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ABSTRACT

Designed for use in vocational education programs, this unit on solar space heating contains information and suggestions for teaching at the secondary school level. It focuses on heating, ventilating, and air conditioning programs. Educational objectives and educational objectives with instructional strategies are provided for each of the eight major concepts of the unit. These concepts include: (1) the sun; (2) active system design; (3) active system solar components; (4) active system installation; (5) active system service; (6) passive system design; (7) energy conservation; and (8) occupations in solar space heating. A basic competency profile chart is presented in the evaluation section. The bibliographic section contains information on publications and media, as well as 40 transparency masters. (ML)

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NEW JERSEY VOCATIONAL-TECHNICAL CURRICULUM LABORATORY
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SOLAR HEATED SPACE SYSTEMS

a Unit of Instruction

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Project staff and participants look forward to your use of these pilot materials and hope you will feel free to suggest improvements.

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FOREWORD

This document is one of four produced for the New Jersey Division of Vocational Education and Career Preparation by the Center for Energy Conservation at Trenton State College, Trenton, New Jersey. In addition to the four documents, four filmstrip/cassettes were also produced. The written documents and media packages deal with one of the following technologies:

1. Solar Heated Domestic Hot Water Systems
2. Solar Heated Space Systems
3. Wind Energy Conversion Systems
4. Heating with Solid Fuels

Curriculum materials were produced over a six month period by selected secondary school, industrial education teachers whose efforts were coordinated by a consultant from one of the state colleges. In all cases, both the teachers and the college consultant who served as the group leader, were selected for their experience and expertise in the particular technology being addressed. The filmstrip/cassette packages were developed and produced by technicians from the Center for Energy Conservation. The preliminary scripts were carefully reviewed and edited by the college consultants, project director and an industrial representative before being finalized.

During the 1980-81 school year each one of the units of instruction was pilot tested in a selected industrial education program within the State of New Jersey.

Further information regarding the availability of these curriculum materials can be obtained by writing to the address listed below:

Vocational-Technical Curriculum Lab
Rutgers - The State University of New Jersey
Building 4103 - Kilmer Campus
New Brunswick, New Jersey 08903

GUIDE FOR USING THIS DOCUMENT

This document attempts to organize a complex body of knowledge into teachable units. Information in the document has been arranged so that the reader is first exposed to the "big picture" or framework of the area under parts of the package. This is accomplished by arranging the information in the following manner:

INTRODUCTION

The introduction provides the reader with basic information on the design and application of the curriculum materials in the document.

UNIT OVERVIEW

The unit overview identifies the major concepts to be covered and a brief description of the subject matter related to each major concept. A suggested period of time for teaching the subject matter has also been included in the unit overview.

CONCEPT OUTLINE OVERVIEW

In this section, the reader can examine more extensively a taxonomy of subject-matter outline of all major concepts. The outline provides a complete listing of the concepts to be covered along with suggested teaching times. Most of the major concepts have been broken down or outlined to the third level, using the numerical system listed below:

1.0	Designates a major or first level.
1.1	Designates a second-level concept.
1.1.1	Designates a third-level concept.

EDUCATIONAL OBJECTIVES

Educational objectives for each major concept are grouped together and can be located by referring to the Table of Contents. Educational objectives, derived from the third level concepts, are numbered accordingly. For example, a third-level concept (1.1.1) might have two objectives which would, therefore, be numbered as 1.1.1.1 and 1.1.1.2.

EDUCATIONAL OBJECTIVES WITH INSTRUCTIONAL STRATEGIES

In this section, each page focuses on a specific third-level concept. The third-level concept will be identified in relationship to the second- and first-level concepts in order to maintain continuity. Educational objectives pertinent to the third-level concept will then be listed. Finally, suggested instructional strategies useful to accomplish the listed objectives are recorded. The strategies are labeled a, b, c, etc. and can be used individually by the teacher or grouped together to facilitate accomplishing the listed objectives.

EVALUATION

This section provides suggestions for evaluating how much has been learned and the degree to which objectives have been accomplished.

BIBLIOGRAPHY

The bibliography serves as a resource guide and contains the following:

1. Overhead Transparency Masters
   These masters can be used to make overhead transparencies. In most instances, the transparency master has been identified for use with a particular instructional strategy.

2. Publications
   A list of books and magazines pertinent to the subject matter or related to an instructional strategy are included in this section. References made to publications in the text of this document are abbreviated and the reader is requested to check the bibliography for a more complete documentation.

3. Films, slides, and Filmstrips
   A list of instructional media which could be used for instruction is included in this section.

   Here again, media referred to in the text of this document are abbreviated and the reader should check the bibliography for more complete documentation.

INTRODUCTION

Solar Space Heating

The unit of instruction, solar space heating, has been designed for use in vocational education programs at the secondary school level. Although most of the concepts within this unit may be used in various vocational and industrial arts education programs, it is primarily intended for use in heating, ventilating, and air conditioning programs (HVAC). One major area dealing with Passive Solar Systems may lend itself to architectural drawing and construction courses moreso than the traditional HVAC program.

Some background information and many fundamental skills were assumed to be an integral part of the HVAC program and, therefore, have not been included in this unit. For example, basic familiarity with hydronic and forced-hot air heating systems and components was assumed to be part of the students' background.

The information in this instructional package is not intended to be a textbook. Rather, it is a grouping of guidance information and teaching recommendations primarily for use by the teacher. These recommendations, concepts, and strategies are laid down in a sequence which may or may not fit the needs of a particular teaching situation. The instructor may wish to change the concept order to tailor this unit to his/her need.

A time frame is given for each teaching concept contained in this unit. These times are provided for guidance only, since the particular instructional strategies chosen will determine the real time needed for accomplishing each objective.

It is assumed that the instructor is familiar with the concepts and topics within this unit. While a specific text is not recommended, references are provided for many concepts to assist the instructor in obtaining in-depth knowledge in these areas. A comprehensive bibliography of teaching/learning materials is also included in this unit. Listed are books, periodicals, films, and other instructional media. Also, a section is provided which includes subject matter masters from which transparencies or ditto masters can be prepared for classroom use.

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UNIT OVERVIEW

Solar Space Heating

MAJOR CONCEPT	OVERVIEW
1.0 The Sun Suggested Instructional Time--2 hours and 30 minutes	A brief history of solar energy usage is covered along with significant developments which have led to today's applications. Characteristics and type of solar radiation are addressed. The legal aspects of solar energy use, including sun rights, is also discussed.
2.0 Active System Design Suggested Instructional Time--3 hours and 30 minutes	Types of active solar space heating systems are explored as well as design, considerations of orientation, building and roof configurations. Basic sizing methods for collectors and storage areas are covered. Cost effectiveness of systems of various types and sizes is explored.
3.0 Active System Solar Components Suggested Instructional Time--9 hours	Exploration of collector types with emphasis on flat-plate collector elements and design is developed. A comparison of air and liquid systems in design, cost, and efficiency is also made. Thermal storage options are considered including rock, water, and salts. Mechanical system components and controls for various system types are studied. Auxilliary Systems and their interface is the final topic in this section.
4.0 Active System Installation Suggested Instructional Time--4 hours and 30 minutes	Collector mounting including orientation, tilt, location options, and protection/penetration is studied. A brief look at storage placement and installation is covered. The mechanics of piping, valving, and control wiring are explored.
5.0 Active System Service Suggested Instructional Time--2 hours and 15 minutes	Emphasis is placed on active liquid system purging and balancing. Electrical testing and troubleshooting of control systems is also covered.
6.0 Passive System Design Suggested Instructional	Basic site and building as well as structural considerations. Study of

	Time--8 hours and 15 minutes	direct and indirect gain systems and alternatives including masonry and water storage and trombe wall design receives considerable emphasis. Isolated gain systems are explored as well.
7.0	Energy Conservation Suggested Instructional Time--2 hours	Energy conservation is critical to the effective use of solar heating systems. Emphasis here is placed on heat loss, and ways in which heat loss can be minimized by insulation, weatherproofing and lifestyle changes.
8.0	Occupations in Solar Space Heating Suggested Instructional Time--2 hours and 30 minutes	A look at careers in solar heating including sales, design, installation, service and maintenance makes up this last concept.

Total Instructional Time--34 hours and 30 minutes

CONCEPT OUTLINE OVERVIEW
Solar Space Heating

1.0	THE SUN	2 hrs 30 mins
	1.1 History	1 hr
	1.1.1 Direct Use in Early Civilizations	30 mins
	1.1.2 Significant Developments	30 mins
	1.2 Solar Radiation	1 hr
	1.2.1 Solar Constant	30 mins
	1.2.2 Variations	30 mins
	1.3 Legal Aspects of the Sun	30 mins
	1.3.1 Building Codes	30 mins
2.0	ACTIVE SYSTEM DESIGN	3 hrs 30 mins
	2.1 Design Considerations	1 hr 45 mins
	2.1.1 Orientation	30 mins
	2.1.2 Building and Roof Design	30 mins
	2.1.3 System Types	45 mins
	2.2 Sizing	1 hr
	2.2.1 Collector Area	30 mins
	2.2.2 Storage	30 mins
	2.3 Economics	45 mins
	2.3.1 Cost-Effectiveness	45 mins
3.0	ACTIVE SYSTEM COMPONENTS	9 hrs
	3.1 Collectors	3 hrs
	3.1.1 Collector Types	1 hr
	3.1.2 Glazing	30 mins
	3.1.3 Coatings/Absorber Types	1 hr
	3.1.4 Collector Design	30 mins
	3.2 Fluids	1 hr 30 mins
	3.2.1 Air	30 mins
	3.2.2 Water	30 mins
	3.2.3 Anti-freeze Types	30 mins

3.3	Storage	2 hrs
3.3.1	Rock/Pebble	30 mins
3.3.2	Water	30 mins
3.3.3	Phase Change Materials	30 mins
3.3.4	Storage Container Options	30 mins
3.4	Mechanical Systems	1 hr 30 mins
3.4.1	Ducts/Blowers	30 mins
3.4.2	Pipe/Pumps	30 mins
3.4.3	Heat Exchangers	30 mins
3.5	Controls	30 mins
3.5.1	Control Components/Functions	30 mins
3.6	Auxilliary Systems	30 mins
3.6.1	Types	30 mins
4.0	ACTIVE SYSTEM INSTALLATION	4 hrs 30 mins
4.1	Collector Mounting	2 hrs
4.1.1	Orientation/Tilt	30 mins
4.1.2	Ground/Roof Options	30 mins
4.1.3	Protection/Penetration/Mounting	1 hr
4.2	Storage	30 mins
4.2.1	Placement/Installation	30 mins
4.3	Piping/Valving	1 hr
4.3.1	Routing	30 mins
4.3.2	Insulation	30 mins
4.4	Control Wiring	1 hr
4.4.1	Routing	30 mins
4.4.2	Sensor Location	30 mins
5.0	ACTIVE SYSTEM SERVICE	2 hrs 15 mins
5.1	Mechanical	1 hr 15 mins
5.1.1	System Purging	30 mins
5.1.2	Balancing	45 mins
5.2	Electrical	1 hr
5.2.1	Testing Procedure	30 mins
5.2.2	Use of Troubleshooting Chart	30 mins

6.0	PASSIVE SYSTEM DESIGN	8 hrs 15 mins
6.1	Building Site Considerations	1 hr 30 mins
6.1.1	Building Location	30 mins
6.1.2	Building Orientation	30 mins
6.1.3	Vegetation	30 mins
6.2	Building Structural Considerations	2 hrs
6.2.1	Above Grade Construction	1 hr
6.2.2	Earth-Sheltered Construction	1 hr
6.3	Direct Gain Systems	2 hrs
6.3.1	Windows, Clerestories and Skylights	45 mins
6.3.2	Masonry Heat Storage	45 mins
6.3.3	Interior Water Storage	30 mins
6.4	Indirect Gain Systems	1 hr 30 mins
6.4.1	Mass Trombe Wall	30 mins
6.4.2	Water Trombe Wall	30 mins
6.4.3	Roof Pond Systems	30 mins
6.5	Isolated Gain Systems	1 hr 15 mins
6.5.1	Sunspace	45 mins
6.5.2	Thermosiphon Systems	30 mins
7.0	ENERGY CONSERVATION	2 hrs
7.1	Heat Loss	1 hr
7.1.1	Infiltration Losses	30 mins
7.1.2	Conduction	30 mins
7.2	Insulation	30 mins
7.2.1	Types and Applications	30 mins
7.3	Life-Style	30 mins
7.3.1	Life-Style Changes	30 mins
8.0	OCCUPATIONS IN SOLAR SPACE HEATING	2 hrs 30 mins
8.1	Sales	30 mins
8.2	Designs	30 mins
8.3	Installer	30 mins
8.4	Electrician	30 mins
8.5	Service and Maintenance Technician	30 mins

CONCEPT 1.0

THE SUN

MAJOR CONCEPT 1.0 - THE SUN

Educational Objectives

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

1.1.1.1 list three examples of solar utilization in early civilizations.

1.1.2.1 outline four significant developments and the approximate dates concerning the use of solar energy from the 1700's to the present.

1.2.1.1 discuss the difference between the solar constant and the solar radiation striking the earth at a particular moment.

1.2.1.2 write or verbalize a brief definition of the solar constant.

1.2.2.1 list four factors affecting the variation of solar radiation striking the earth at a given location.

1.2.2.2 using the correct charts, determine the available solar energy in BTU's for any hour, day and month at a specified latitude.

1.3.1.1 explain the need for incorporating regulations into building codes which will protect the rights of the solar homeowner.

1.3.1.2 discuss the possible future need for "sun rights," a legal document insuring an individual's right to access to solar energy.

MAJOR CONCEPT 1.0 THE SUN **TIME** 30 mins.

1.1 History

1.1.1 Direct Use in Early Civilizations

OBJECTIVES	STRATEGIES
1.1.1.1 List three examples of solar utilization in early civilizations.	a. Lead class discussion on early use of solar. Ask students to list what they believe would have been the early uses of solar energy (i.e. food drying, heat).* b. Give students a library assignment to find three examples of the use of solar energy in early civilizations.

NOTES:
*Meinel and Meinel, Applied Solar Energy: An Introduction. Chapter 1.

MAJOR CONCEPT 1.0 THE SUN **TIME** 30 mins.

1.2 History

1.1.2 Significant Developments

OBJECTIVES	STRATEGIES
1.1.2.1 Outline four significant developments and the approximate dates concerning the use of solar energy from the 1700's to the present.	a. Lead a class discussion on the important solar energy developments in recent history.* b. Make a bulletin board which contains a time-line describing significant solar developments.

NOTES:

*Meinel and Meinel. Applied Solar Energy: An Introduction. Chapter 1.

MAJOR CONCEPT 1.0 THE SUN **TIME** 30 mins.

1.2 Solar Radiation

1.2.1 Solar Constant

OBJECTIVES		STRATEGIES	
1.2.1.1	Discuss the difference between the solar constant and the solar radiation striking the earth at a particular moment.	a.	Discuss the definition of solar "constant."
1.2.1.2	Write or verbalize a brief definition of the solar constant.		

NOTES:

MAJOR CONCEPT 1.0 THE SUN **TIME** 30 mins.

1.2 Solar Radiation

1.2.2 Variations

OBJECTIVES	STRATEGIES
1.2.2.1 List four factors affecting the variation of solar radiation striking the earth at a given location.	a. Moderate a class discussion on variations in solar radiation due to earth's tilt, seasonal/ monthly changes, and hourly changes.*
1.2.2.2 Using the correct charts, determine the available solar energy in BTU's for any hour, day and month at a specified latitude.	b. Define "langley" for class and discuss charts which provide solar radiation information for various latitudes, months, days and hours.*
	c. Have students complete assignment #33 entitled Measuring Energy from the Sun.**
	d. Ask students to try and plot the sun's location for a summer day and for a winter day for each hour. Discuss variations with class.
	e. Demonstrate chart use by overhead transparency of sample chart for latitude of the school.***
	f. Assign each student a different state capitol and have each determine the available solar energy for noon on January 21 (per hour).

NOTES:

*See Northeast Solar Energy Education Center, Solar Energy Adult Education Curriculum Project for transparency masters.

**DOE Solar Energy Project. Activities-Chemistry & Physics, Anderson, pp. 287-296.

***Meinel and Meinel, Applied Solar Energy: An Introduction, pp. 39-115.

MAJOR CONCEPT 1.0 THE SUN **TIME** 30 mins.

1.3 Legal Aspects of the Sun

1.3.1 Building Codes

OBJECTIVES	STRATEGIES
1.3.1.1 Explain the need for incorporating regulations into building codes which will protect the rights of the solar homeowner.	a. Have students "brainstorm" situations where problems could develop for a solar homeowner through changes outside his property or legal limits.
1.3.1.2 Discuss the possible future need for "sun rights," a legal document insuring an individual's right to access to solar energy.	b. Have students suggest possible regulations which might help control the problems that may develop for the solar homeowner. c. Through discussion have class develop a hypothetical set of "sun rights."

NOTES:

Sheet Metal and Air Conditioning Contractors National Association, Fundamentals of Solar Heating. 1978 pp. 11-1 to 11-5.

CONCEPT 2.0

ACTIVE SYSTEM DESIGN

MAJOR CONCEPT 2.0 - ACTIVE SYSTEM DESIGN

Educational Objectives

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

2.1.1.1 list at least five significant design considerations which should be part of a structure to be incorporated with active solar space heating.

2.1.1.2 recall approximate loss percentage of solar radiation when collectors are oriented up to 15° east or 15° west of true south.

2.1.2.1 list at least three solar collector mounting location options.

2.1.2.2 sketch at least three roof designs suitable for mounting large space heating collector arrays.

2.1.3.1 list three advantages and three disadvantages of air-type solar systems.

2.1.3.2 list three advantages and three disadvantages of liquid-type solar systems.

2.2.1.1 using charts provided, determine the collector area required to provide about 50% of the heat load for a particular given dwelling.

2.2.2.1 describe three factors affecting the thermal storage size in an active solar system.

2.2.2.2 given the necessary data, calculate the storage mass in both water and rock for a 500 square foot collector.

2.3.1.1 describe at least 10 considerations which effect the life-cycle costs of a combination solar/conventional heating system.

MAJOR CONCEPT 2.0 ACTIVE SYSTEM DESIGN **TIME** 30 mins.

2.1 Design Consideration

2.1.1 Orientation

OBJECTIVES		STRATEGIES	
2.1.1.1	List at least five significant design considerations which should be part of a structure to be incorporated with active solar space heating.	a.	Visit a commercial structure or residence which incorporates active solar space heating. (See bibliography which contains addresses of solar buildings in New Jersey).
2.1.1.2	Recall approximate loss percentage of solar radiation when collectors are oriented up to 15° east or 15° west of true south.	b.	Have students discuss what they believe would be important to incorporate into a dwelling with solar space heating.*
		c.	Lecture on the importance of siting a solar house with respect to true south.

NOTES:

*Ruhle & Associates, Solar Homes. Slides with tapes or Curriere & Fraserday, Solar Houses for a Cold Climate. Publication.

MAJOR CONCEPT 2.0 ACTIVE DESIGN SYSTEM **TIME** 30 mins.

2.1 Design Considerations

2.1.2 Building and Roof Design

OBJECTIVES	STRATEGIES
2.1.2.1 List at least three solar collector mounting location options.	a. Show visuals of mounting positions including ground, roof, and vertical wall locations.
2.1.2.2 Sketch at least three roof designs suitable for mounting large space heating collector arrays.	b. Show transparencies of various roof designs suitable for solar collector mounting.* Transparency #1.
	c. Have students sketch roof designs capable of handling 200 square feet of solar collectors.

NOTES:

*Sheet Metal and Air Conditioning Contractors National Association, Fundamentals of Solar Heating, p. 9-5, 1978.

MAJOR CONCEPT 2.0 ACTIVE SYSTEM DESIGN **TIME** 45 mins.

2.1 Design Considerations

2.1.3 System Types

OBJECTIVES	STRATEGIES
2.1.3.1 List three advantages and three disadvantages of air-type solar systems.	a. Show film "Building Solar" by Heliotherm which compares air and liquid solar systems.
2.1.3.2 List three advantages and three disadvantages of liquid-type solar systems.	b. Show visuals of air and liquid solar systems and have students discuss the advantages and disadvantages of each type.* Transparencies #2 and #3.

NOTES:

*Sheet Metal and Air Conditioning Contractors National Association, Fundamentals of Solar Heating, p. 1-7, 1978.

MAJOR CONCEPT 2.0 ACTIVE SYSTEM DESIGN **TIME** 30 mins.

2.2 Sizing

2.2.1 Collector Area

OBJECTIVES	STRATEGIES
2.2.1.1 Using charts provided, determine the collector area required to provide about 50% of the heat load for a particular given dwelling.	a. Show students examples of charts used to choose collector area. Provide handouts of these charts and discuss, using overhead of charts.* Transparency #4.

NOTES:

*Two examples of sizing charts and their use are available in Sheet Metal and Air Conditioning Contractors National Association, Fundamentals of Solar Heating. 1978.

*Solar system sizing charts: R.H. Montgomery, The Solar Decision Book, A-8-A-25.

MAJOR CONCEPT 2.0 ACTIVE SYSTEM DESIGN **TIME** 30 mins.

2.2 Sizing

2.2.2 Storage

OBJECTIVES	STRATEGIES
2.2.2.1 Describe three factors affecting the thermal storage size in an active solar system.	a. Discuss specific heat of various materials including rock and water. Use a transparency which shows the specific heat of materials.* Transparency #5.
2.2.2.2 Given the necessary data, calculate the storage mass in both water and rock for a 500 square foot collector.	b. Demonstrate use of "rules of thumb" for calculating thermal mass for storage* **, ***

NOTES:

*Bruce Anderson, Solar Energy: Fundamentals in Building Design, Appendix D, pp. 348-351.

**Anderson, pp. 227-234; also Fundamentals of Solar Heating. pp. 6-8 to 6-9.

***Solar Energy Applications Laboratory, Colorado State University, Design of Systems: Training Manual. p. 6-3, 6-4.

MAJOR CONCEPT 2.0 ACTIVE SYSTEM DESIGN **TIME** 45 mins.

2.3 Economics

2.3.1 Cost-Effectiveness

OBJECTIVES	STRATEGIES
2.3.1.1 Describe at least 10 considerations which effect the life-cycle costs of a combination solar/conventional heating system.	a. Have students make a list of the factors they feel affect the cost of a solar heating systems over the expected life of the system.* b. Discuss income and property tax incentives for solar space heating currently applicable. Transparency #6. c. Show students various charts and tables which may be used to figure pay-back periods for various solar systems.*

NOTES:

*Sheet Metal and Air Conditioning Contractors National Association, Fundamentals of Solar Heating. 1978, pp. 6-6 to 6-7.

CONCEPT 3.0

ACTIVE SYSTEM COMPONENTS

MAJOR CONCEPT 3.0 - ACTIVE SYSTEM SOLAR COMPONENTS

Educational Objectives

The following objectives provide the teacher with an overview of the concepts and skills contained in this section

The student will be able to:

3.1.1.1 describe three basic types of collectors.

3.1.1.2 describe at least four different liquid and four air-type absorber configurations.

3.1.2.1 list and describe three qualities important to good glazing materials.

3.1.2.2 list four different types of collector glazing materials.

3.1.3.1 list and describe three qualities of absorber coatings.

3.1.3.2 diagram two air and two liquid absorber types.

3.1.4.1 explain the need for insulating a solar collector.

3.1.4.2 draw a diagram of a cross-section of a liquid or air-type collector labeling each part.

3.2.1.1 list two advantages and two disadvantages of air as the transfer medium in a solar collection system.

3.2.2.1 list two advantages and two disadvantages of water as the fluid in a solar collection system.

3.2.3.1 compare the characteristics of three types of anti-freeze solutions used in liquid solar systems.

3.3.1.1 diagram the essential elements of a rock bed storage system.

3.3.2.1 diagram and label the essential elements of a water storage system for liquid solar space heating.

3.3.3.1 discuss the qualities of phase change materials which make them attractive for solar thermal storage.

3.3.4.1 compare water, rock-bed and salt storage systems.

3.4.1.1 describe the additional requirements of the solar air-type system over the conventional forced-hot air heating system.

3.4.2.1 describe the types and sizes of pumps used in hydronic solar systems.

3.4.2.2 describe the need for the following components in the solar hydronic system: check value, expansion tank, pressure relief value, air vent, balance value.

3.4.3.1 explain the function of a heat exchanger in a solar system.

3.4.3.2 list and describe three types of heat exchangers.

3.5.1.1 describe the function of sensors, differential thermostats and room thermostats.

3.6.1.1 list the types of back up systems appropriate for use with active solar systems.

3.6.1.2 describe several methods used to interface back up systems with solar heating systems.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 1 hr.

3.1 Collectors

3.1.1 Collector Types

OBJECTIVES		STRATEGIES
3.1.1.1	Describe three basic types of collectors.	a. Give a lecture on collector types using models, visuals, and active collectors. Include flat-plate, concentrating and evacuated tube collectors.* Transparency #7.
3.1.1.2	Describe at least four different liquid and four air-type absorber configurations.	b. Have students design and build small air-type absorbers using different types of found materials.** c. Have students write to manufacturers for product information on collectors.***

NOTES:

*Bruce Anderson, Solar Energy: Fundamentals in Building Design, pp. 147-214.

**Suggested materials include metal beverage cans, steel, aluminum, or copper sheets, metal lath, etc. See also "Construction of a Flat Plate Air Flow Solar Collector" in DOE Solar Energy Project, Activities in Chemistry and Physics.

***A list of collector manufacturers can be found in Solar Engineering Master Catalog, Solar Engineering Publishers, Inc., 1979.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins

3.1 Collectors

3.1.2 Glazing

OBJECTIVES	STRATEGIES
3.1.2.1 List and describe three qualities important to good glazing materials. 3.1.2.2 List four different types of collector glazing materials.	a. Show students different types of glazing materials including good and poor quality glass, fiber-glass reinforced polyester, acrylic-type materials, and thin plastic films. Discuss the advantages and disadvantages of each type.*

NOTES:

*A list of alternatives to glass is included in Bruce Anderson, Solar Energy: Fundamentals of Building Design, p. 161.

*A sample of SUN-LITE is available from Kalwall Solar Components, P.O. Box 237, Manchester, N.H. 03105.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 1 hr

3.1 Collectors

3.1.3 Coatings/Absorber Types

OBJECTIVES	STRATEGIES
3.1.3.1 List and describe three qualities of absorber coatings. 3.1.3.2 Diagram two air and two liquid absorber types.	a. Show students examples of different absorber coatings and discuss the properties of: 1) absorption, 2) thermal resistance between plate and the transfer medium, and 3) emissivity of the coating.* Transparency #8. b. Test different absorber coatings using several pieces of metal cut to one square foot. Coat each piece with a different material and place on top of snow on a sunny day. Pieces with the greatest penetration into the snow have absorbed the greatest amount of solar radiation. See also, A Comparison of Absorber Plate Coatings in DOE Solar Energy Project, Activities in Chemistry and Physics. c. Discuss selective surfaces. Describe types, costs and effectiveness.* d. Show examples of different air and liquid absorber types. Transparencies #9 and #10.

NOTES:

*Bruce, Anderson Solar Energy: Fundamentals of Building Design discusses coatings and selective surfaces, pp. 156-158. Also, Meinel and Meinel Applied Solar Energy, pp. 263-315.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.1 Collectors

3.1.4 Collector Design

OBJECTIVES	STRATEGIES
3.1.4.1 Explain the need for insulating a solar collector. 3.1.4.2 Draw a diagram of a cross-section of a liquid or air-type collector and label each part.	a. Show students an actual liquid collector and point out the construction details of insulation, frame construction, absorber plate, surface coating, glazing and fluid corrections.* b. Using overhead transparencies, show students the construction of a typical solar collector. Transparency #11. c. For homework assign activity #2 "Collecting the Sun's Energy" from DOE Solar Energy Project-Activities Junior High Science.

NOTES:

*See also Cooper Solar-Ed. Corp., Flat Flat Collectors, 60 slides.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.2 Fluids

3.2.1 Air

OBJECTIVES	STRATEGIES
3.2.1.1 List two advantages and two disadvantages of air as the transfer medium in a solar collection system.	a. Discuss the differences between air and water as heat transfer mediums.* b. Ask students to list advantages and disadvantages of air-type solar collection/storage systems. c. Show transparency of air-type solar space heating system and discuss efficiency, storage options, and cost. Transparency #12.

NOTES:

*Bruce Anderson Solar Energy: Fundamentals in Building Design discusses heat transfer in air and liquid systems, pp. 142-145.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.2 Fluids

3.2.2 Water

OBJECTIVES	STRATEGIES
3.2.2.1 List two advantages and two disadvantages of water as the fluid in a solar collection system.	a. Discuss the differences between air and water as heat transfer mediums. b. Ask students to list advantages and disadvantages of liquid-type solar collection/storage systems. c. Show transparency of liquid-type solar space system and discuss efficiency, storage options, cost, etc. Transparency #3.

NOTES:

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.2 Fluids

3.2.3 Anti-freeze Types

OBJECTIVES	STRATEGIES
3.2.3.1 Compare the characteristics of three types of anti-freeze solutions used in liquid solar systems.	a. Show students examples of three types of anti-freezes: a) ethylene glycol, b) propylene glycol, and c) silicone fluid. b. Discuss properties of anti-freezes which make them desirable or undesirable.

NOTES:

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.3 Storage

3.3.1 Rock/Pebble

OBJECTIVES	STRATEGIES
3.3.1.1 Diagram the essential elements of a rock bed storage system.	a. Visit a solar heated dwelling which uses a rock bed storage system. b. Show a film*, transparency, slide* or a diagram of a rock bed thermal storage for an air-type system. Transparency #13. c. Discuss specific heat of rock and compare to other materials. d. Construct pebble storage demonstration unit as outlined in Activity 4-Energy Storage in DOE Solar Energy Project Junior High School Science activities.

NOTES:

*16mm film from Heliotherm "Building Solar" includes good section on installation of a rock bed storage area. See also Cooper Solar-Ed. Corp., Energy Storage, 25 slides.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.3 Storage

3.3.2 Water

OBJECTIVES	STRATEGIES
3.3.2.1 Diagram and label the essential elements of a water storage system for liquid solar space heating.	a. Show a film*, transparency, slide or diagram of a water storage system for a liquid solar system. Transparency #14. b. Visit a solar heated building which uses water storage. c. Discuss specific heat of water and its implications to using water as a heat storage medium. d. Discuss with students the types of storage containers suitable for water storage.**

NOTES:

*16mm film from Heliotherm "Building Solar" includes good section on water storage. See also Cooper Solar-Ed. Co., Energy Storage, 25 slides.

**Sheet Metal and Air Conditioning Contractors National Association, Fundamentals of Solar Heating, 1978, pp. 4-7 to 4-10.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.3 Storage

3.3.3 Phase Change Materials

OBJECTIVES	STRATEGIES
3.3.3.1 Discuss the qualities of phase change materials which make them attractive for solar thermal storage.	a. Lecture on the types of eutectic salts used in experimental heat storage systems and describe how change of state increases heat retaining qualities.* b. Have students write to manufacturers of salts for product information (see Bibliography). c. Have students research recent articles on salts as heat storage medium. d. Have a group of students perform Activity 35 Solar Energy and the Heat of Hydration in DOE Solar Energy Project-Activities in Chemistry and Physics.

NOTES:

*Bruce Anderson Solar Energy: Fundamentals in Building Design, 1977, pp. 224-227.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.3 Storage

3.3.4 Storage Container Options

OBJECTIVES	STRATEGIES
3.3.4.1 Compare water, rock-bed and salt storage systems.	a. Have students make a materials list with approximate costs of the three storage systems. b. Invite one representative from each system area to come to class to discuss advantages and disadvantages of their systems. c. Invite a contractor or installer to class to discuss advantages and disadvantages of each system. d. Have students write to manufacturers for product literature and report to class on findings. e. Organize a field trip to local manufacturer or installation site. f. Build model or full-size system and test for temperature retention.*

NOTES:
*See strategy d. under objective 3.3.1.1.

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.4 Mechanical Systems

3.4.1 Ducts/Blowers

OBJECTIVES	STRATEGIES
3.4.1.1 Describe the additional requirements of the solar air-type system over the conventional forced-hot air heating system.	a. Show 16mm film "Building Solar" by Heliotherm which depicts the function of various components in the air-type solar system. b. Relate air-type solar heating systems to conventional forced hot air heating systems in terms of ducting and blowers. Note additional system resistance due to collectors and storage, automatic dampers, etc. See Transparency #15.

NOTES:

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.4 Mechanical Systems

3.4.2 Pipe/Pumps

OBJECTIVES		STRATEGIES
3.4.2.1	Describe the types and sizes of pumps used in hydronic solar systems.	a. Using transparency depicting plumbing diagram of solar hydronic system discuss the various components and the function and operation of each. Transparency #16 through #20.
3.4.2.2	Describe the need for the following components in the solar hydronic system: check value, expansion tank, pressure relief value, air vent, balance value.	b. Show 16mm film "Building Solar" by Heliotherm which depicts the function of various components of the liquid solar system.

NOTES:

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.4 Mechanical Systems

3.4.3 Heat Exchangers

OBJECTIVES	STRATEGIES
3.4.3.1 Explain the function of a heat exchanger in a solar system.	a. Discuss the types of heat exchangers and their function. Transparencies #21 and #22.
3.4.3.2 List and describe three types of heat exchangers.	b. Have students discuss and/or list common heat exchangers found in daily life.

NOTES:

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.5 Controls

3.5.1 Control Components/Functions

OBJECTIVES	STRATEGIES
3.5.1.1 Describe the function of sensors, differential thermostats and room thermostats.	a. Show examples of various temperature sensors and differential thermostat, and have students describe function of each. b. Discuss the use of differential thermostats using a transparency of hydronic closed-loop and air-type solar heating systems. Discuss automatic damper operation on air system. Transparency #23.

NOTES:

MAJOR CONCEPT 3.0 ACTIVE SYSTEM SOLAR COMPONENTS **TIME** 30 mins.

3.6 Auxiliary Systems

3.6.1 Types

OBJECTIVES	STRATEGIES
3.6.1.1 List the types of back up systems suitable for active solar systems.	a. Discuss the advantages and disadvantages of different types.
3.6.1.2 Describe several methods used to interface back up systems with solar heating systems.	b. Discuss solar assisted heat-pumps as an interface with solar and back up heating systems. Transparency #24.

NOTES:

CONCEPT 4.0

ACTIVE SYSTEM INSTALLATION

MAJOR CONCEPT 4.0 - ACTIVE SYSTEM INSTALLATION

Educational Objectives

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

4.1.1.1 determine the optimum tilt angle for a solar collector for any given latitude.

4.1.2.1 discuss two advantages and two disadvantages for both roof and ground collector mounting.

4.1.3.1 describe at least one accepted method of roof mounting a collector on a completed structure.

4.2.1.1 describe three installation factors that will affect the efficiency of a rock-bed storage system.

4.3.1.1 discuss pipe and duct installation techniques including insulation, jointing horizontal and vertical runs, and necessary valving.

4.3.2.1 discuss suggested insulation standards for piping and ducts including material types, thicknesses and R-values.

4.4.1.1 describe control wire installation procedures using manufacturers product information.

4.4.2.1 list three temperature sensor locations and describe how each should be installed for optimum efficiency.

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 30 mins.

4.1 Collector Mounting

4.1.1 Orientation/Tilt

OBJECTIVES	STRATEGIES
4.1.1.1 Determine the optimum tilt angle for a solar collector for any given latitude.	a. Lecture/discussion on the variations that different tilt angles will have on collector efficiency. b. Using overhead transparency, show why the collector interception angle is important. Transparency #25. c. Discuss orientation of collectors and allowable variations from true south.

NOTES:

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 30 mins.

4.1 Collector Mounting

4.1.2 Ground/Roof Options

OBJECTIVES	STRATEGIES
4.1.2.1 Discuss two advantages and two disadvantages for both roof and ground collector mounting.	a. Discuss collector mounting location options. b. Have students suggest advantages and disadvantages of various mounting positions.

NOTES:

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 1 hr.

4.1 Collector Mounting

4.1.3 Protection/Penetration/Mounting

OBJECTIVES	STRATEGIES
4.1.3.1 Describe at least one accepted method of roof mounting a collector on a completed structure.	a. Discuss roof mounting and weather-proofing.* Transparency #26. b. Using mock-up of roof structure, demonstrate a procedure for collector mounting and the roof penetration. c. Show 16mm film "Solar Heating Systems" by Heliotherm which describes the collector mounting procedures for both liquid and air systems. d. Have students: 1) mount a collector on an actual roof or roof mock-up; 2) make roof penetration; 3) weather proof installation.

NOTES:

*See also Cooper Solar-Ed Corp., Flat Plate Collections, 60 slides.

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 30 mins.

4.2 Storage

4.2.1 Placement/Installation

OBJECTIVES	STRATEGIES
4.2.1.1 Describe three installation factors that will affect the efficiency of a rock-bed storage system.	a. Discuss insulation requirements for rock-bed and water thermal storage. b. Show 16mm film "Building Solar" by Heliotherm which demonstrates the procedure for rock-bed installation and emphasizes the importance of insulation, elimination of air leaks, and use of correct size stove for storage*

NOTES:

*See also Cooper Solar-Ed Corp., Energy Storage, 25 slides.

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 30 mins.

4.3 Piping/Valving

4.3.1 Routing

OBJECTIVES	STRATEGIES
4.3.1.1 Discuss pipe and duct installation techniques including insulation, jointing horizontal and vertical runs, and necessary valving.	a. Show 16mm film "Building Solar" by Heliotherm which describes piping and duct routing in solar systems. b. Show class various solar air and liquid systems by using films, slides, books, etc. and discuss various valving and routing problems with class.** c. On a "live" solar heating system show students collector feed and return routing and discuss problems and possible solutions.

NOTES:

*See slide series Cooper Solar-Ed. Corp, Flat Plate Collectors, 60 slides.
**See Sheet Metal and Air Conditioning Contractors National Association, Fundamentals of Solar Heating, Figures 5-28 through 5-31.

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 30 mins.

4.3 Piping/Valving

4.3.2 Insulation

OBJECTIVES	STRATEGIES
4.3.2.1 Discuss suggested insulation standards for piping and ducts including material types, thicknesses and R-values.	a. Show 16mm film "Building Solar" by Heliotherm which discusses pipe and duct insulation. b. Show students various samples of pipe and duct insulation and discuss R-values, costs, materials.

NOTES:

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 30 mins.

4.4 Control Wiring

4.4.1 Routing

OBJECTIVES	STRATEGIES
4.4.1.1 Describe control wire installation procedures using manufacturer's product information.	a. Show students various control systems, sensor devices and product information/installation procedures sheets. b. Have students wire actual or mock-up system according to manufacturer's specifications.

NOTES:

MAJOR CONCEPT 4.0 ACTIVE SYSTEM INSTALLATION **TIME** 30 mins.

4.4 Control Wiring

4.4.2 Sensor Location

OBJECTIVES	STRATEGIES
4.4.2.1 List the three temperature sensor locations and describe how each should be installed for optimum efficiency.	a. Show an actual solar heating system collector sensor, thermal storage sensor, and room temperature sensor. Discuss locations for each sensor and emphasize system efficiency. b. Show overhead, slide, etc. of solar heating system schematic and locate sensors. Emphasizing efficiency, discuss with class collector sensor location, storage sensor location, and room thermostat location. Transparency #27 and #28.

NOTES:

CONCEPT 5.0

ACTIVE SYSTEM SERVICE

MAJOR CONCEPT 5.0 - ACTIVE SYSTEM SERVICE

Educational Objectives

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

5.1.1.1 explain the need for purging a hydronic solar heating system.

5.1.1.2 purge a liquid solar system after identifying collectors which have improper fluid flow.

5.1.2.1 explain the need for a balanced flow through each collector.

5.1.2.2 balance the flow in a liquid solar space heating system by checking and adjusting the flow rate through each collector.

5.2.1.1 follow manufacturer's recommended testing procedures for tracing malfunctions in differential thermostats.

5.2.1.2 follow manufacturer's recommended testing procedures for checking temperature sensors.

5.2.2.1 use a simple electrical troubleshooting chart to trace a problem in a solar system control circuit.

MAJOR CONCEPT 5.0 ACTIVE SYSTEM SERVICE **TIME** 30 mins.

5.1 Mechanical

5.1.1 System Purging

OBJECTIVES	STRATEGIES
5.1.1.1 Explain the need for purging a hydronic solar heating system.	a. Discuss importance of purging a liquid system and show manual procedures with aid of visuals.
5.1.1.2 Purge a liquid solar system after identifying collectors which have improper fluid flow.	b. Show students procedures for purging a liquid solar system (may be solar heated domestic hot water system).
	c. Have students take apart an automatic air vent in order to see how it works. Discuss different types of automatic vents. (AMTROL: AM-701 or AM-703).

NOTES:

MAJOR CONCEPT 5.0 ACTIVE SYSTEM SERVICE **TIME** 45 mins.

5.1 Mechanical

5.1.2 Balancing

OBJECTIVES	STRATEGIES
5.1.2.1 Explain the need for a balanced flow through each collector.	a. Discuss the need for balancing values and their operation in a collector array.
5.1.2.2 Balance the flow in a liquid solar space heating system by checking and adjusting the flow rate through each collector.	b. Use manufacturer's specifications from various collectors to point out differences in flow rates and efficiencies. c. Using a system equipped with balancing valves, demonstrate resultant flow changes and collector output temperature changes. d. Have students write to manufacturers for product information on flow meters and collectors e. Have students vary the flow rate through a liquid system by checking temperature changes across collectors.

NOTES:

MAJOR CONCEPT 5.0 ACTIVE SYSTEM SERVICE **TIME** 30 mins.

5.2 Electrical

5.2.1 Testing Procedure

OBJECTIVES	STRATEGIES
5.2.1.1 Follow manufacturer's recomended testing procedures for tracing malfunctions in differential thermostats.	a. Show students an example of manufacturer's testing procedures for both sensors and differential thermostats.*
5.2.1.2 Follow manufacturer's recommended testing procedures for checking temperature sensors.	b. Show slide series** dealing with measurement and control or use transparencies #29 and #30.
	c. Have students use manufacturer's testing procedure to check an operable differential thermostat.

NOTES:

*Sheet Metal and Air Conditioning Constractors National Association, Fundamentals of Solar Heating. 1978, figures 10-5, 10-6 and 10-3, p. 10-2.

**Copper Solar-Ed. Co., Measurement and Control Systems, 25 slides.

MAJOR CONCEPT 5.0 ACTIVE SYSTEM SERVICE **TIME** 30 mins.

5.2 Electrical

5.2.2 Use of Troubleshooting Chart

OBJECTIVES	STRATEGIES
5.2.2.1 Use a simple electrical troubleshooting chart to trace a problem in a solar system control circuit.	a. Discuss how troubleshooting charts are used. Introduce discussion with the use of a troubleshooting chart on automotive starting problems. b. Show students a troubleshooting chart for a solar air or hydronic heating system. Discuss step-by-step procedures for following chart. c. Have students write to manufacturers for their troubleshooting charts on solar space heating systems. d. Have students use troubleshooting charts to find problems on actual solar heating or domestic hot water control systems. e. Use slide series to point out problem areas in control circuits*

NOTES:

*See Cooper Solar-Ed Co., Measurement and Control Systems, 25 slides.

CONCEPT 6.0

PASSIVE SYSTEM DESIGN

MAJOR CONCEPT 6.0 - PASSIVE SYSTEM DESIGN

Educational Objectives

6.1.1.1 determine the suitability of a site for a solar heated structure by using a topographic map showing contours, compass heading, and prominent on/near site features.

6.1.1.2 select the optimum location on the site for a dwelling; assume a suitable site and consider local set-back requirements.

6.1.2.1 explain or describe the necessity of an unobstructed southern exposure.

6.1.2.2 use a compass and transit in staking out a structure.

6.1.1.3 determine what existing vegetation must be removed to enhance solar collection potential of a site.

6.1.3.2 select the types and location for various kinds of vegetation to provide optimal sun, shade and windbreak, and to prevent erosion.

6.2.1.1 demonstrate or describe energy conserving measures regarding window and door placement, arrangement of interior spaces and insulation techniques.

6.2.1.2 demonstrate or describe use of roof projections or other integral sun-shading devices to seasonally optimize interior temperatures.

6.2.1.3 explain the effects of berming and design berms that provide the desired level of insulation.

6.2.2.1 explain the theory of thermal efficiency of subterranean structures.

6.2.2.2 explain design considerations such as soil types, drainage and moisture control, load support, etc., peculiar to earth-sheltered structures.

6.3.1.1 calculate the recommended range (in square feet) of south-facing glass for a 1500 sq. ft. dwelling in a given climate.

6.3.1.2 discuss the advantages and disadvantages of north, east and west facing glass area in terms of heat gain and loss during a heating season.

6.3.1.3 describe or define a direct gain system.

6.3.2.1 discuss the use of masonry thermal storage by emphasizing the following factors: location, size, and distribution of thermal mass.

6.3.2.2 describe the difference in heat transfer properties of water and masonry in a direct gain system.

6.3.2.3 locate the recommended figures and calculate the amount of double glazed masonry thermal storage wall for an 800 sq. ft. dwelling area.

6.3.3.1 recall the amount of water (cubic feet or gallons) recommended for each square foot of solar window.

6.3.3.2 describe the difference in heat transfer properties of water and masonry in a direct gain syste

6.3.3.3 calculate the number of BTU's that one cubic foot of water can store with a 50 degree temperature rise.

6.4.1.1 describe or define a mass Trombe wall system and explain how it functions.

6.4.1.2 calculate the approximate heating contribution of a mass Trombe wall system to the heating requirements of a particular structure.

6.4.1.3 incorporate a mass Trombe wall system in a design of a dwelling.

6.4.2.1 describe or define a water Trombe wall system and explain how it functions .

6.4.2.2 calculate the approximate heating contribution of a water Trombe wall system to the heating requirements of a particular structure.

6.4.2.3 incorporate a water Trombe wall system in the design of a dwelling.

6.4.3.1 describe the way a roof pond system functions to heat and/or cool a building.

6.4.3.2 describe critical design considerations for roof pond systems.

6.4.3.3 incorporate a roof pond system in the design of a building.

6.5.1.1 describe the basic characteristics and functioning of a sunspace (greenhouse) system.

6.5.1.2 calculate the potential heat contribution of a sunspace system.

6.5.1.3 design a structure incorporating a sunspace system.

6.5.2.1 describe the basic elements of design and explain the functioning of a thermosiphon system.

6.5.2.2 explain how a thermosiphon system is controlled to prevent excessive heat gain/loss.

6.5.2.3 be able to design a thermosiphoning system using either air or water as the heat transfer medium.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.1 Building Site Considerations

6.1.1 Building Location

OBJECTIVES	STRATEGIES
6.1.1.1 Determine the suitability of a site for a solar heated structure by using a topographic map showing contours, compass heading and prominent on/near site features.	a. Illustrated lecture on aspects which determine suitability of any site.*
	b. Discussion of particular site suitability based on topographic maps of suitable and unsuitable sites.
6.1.1.2 Select the optimum location on the site for a dwelling; assume a suitable site and consider local set-back requirements.	c. Field trip to a suitable and unsuitable site.
	d. Construction of a site model.**
	e. Show 16mm film "Sun Builders," available from D.O.E., which illustrates passive solar dwellings.

NOTES:

*E. Mazria The Passive Solar Energy Book, pp. 73-77, and AIA Research Corporation's Regional Guidelines for Building Passive Energy Conserving Homes.

**See activity #37, A Passive Solar Energy House in D.O.E. Solar Energy Project--Activities General Solar Topics.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.1 Building Site Considerations

6.1.2 Building Orientation

OBJECTIVES	STRATEGIES
6.1.2.1 Explain or describe the necessity of an unobstructed southern exposure.	a. Assign reading for discussion of the basics of solar gain.
6.1.2.2 Use a compass and transit in staking out a structure.	b. Show movie or slides depicting and describing existing solar heated structures.**
	c. Organize field trip to existing solar heated structure.*
	d. Devise experiments designed to demonstrate solar gain through windows facing to the four points of the compass.
	e. Practice classroom exercises on use of compass and transit.
	f. Do classroom exercises on building stake-out procedures.
	g. Stage on-site practice problems using compass and transit to stake out a building.

NOTES:

*See E. Mazria , The Passive Solar Energy Book, p. 25, 81, 88.
**NSHCIC-Selected Residential Solar Heated Buildings in N.J., 1980.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.1 Building Site Considerations

6.1.3 Vegetation

OBJECTIVES		STRATEGIES
6.1.3.1	Determine what existing vegetation must be removed to enhance solar collection potential of a site.	a. Lecture/discussion of the seasonal sun, shade or windbreak qualities of various types of trees and shrubs. Transparency #31.
6.1.3.2	Select the types and location for various kinds of vegetation to provide optimal sun, shade and windbreak, and to prevent erosion.	b. Createclassroom exercise to determine the length of shadows cast by trees of varying types and sizes at different seasons. c. Plan a field trip to a site where classroom exercises would be applied to identify trees whose removal optimizes solar collection potential. d. Prepare landscaping plan designed to produce optimum sun, shade or windbreak for a dwelling on a particular site. See also note under 6.1.1 e. Contact County Extension Agent for material on the use of vegetation to control erosion.

NOTES:

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 1 hr.

6.2 Building Structural Considerations

6.2.1 Above Grade Construction

OBJECTIVES	STRATEGIES
6.2.1.1 Demonstrate or describe energy conserving measures regarding window and door placement, arrangement of interior spaces and insulation techniques.	a. Discuss heat loss/gain related to window and door location and to insulation amount and type.
6.2.1.2 Demonstrate or describe use of roof projections or other integral sun-shading devices to seasonally optimize interior temperatures.	b. Calculate heat losses for buildings of similar size but with different positions for windows and doors relative to sun and prevailing winds.
6.2.1.3 Explain the effects of berming and design berms that provide the desired level of insulation.	c. Discuss effect of interior space arrangement on heating/cooling efficiency. Transparency #32.
	d. Use visual aids or field trips to existing buildings to show effect of structural shading devices on heat gain at different seasons.*, ** Transparency #33.
	e. Using a house model and strong light source, demonstrate effect of structural shading devices through simulated seasonal solar angle changes.
	f. Discuss thermal characteristics of soils under different moisture and material content (sand, clay, etc.) conditions.

NOTES:

It is assumed the "R" value of different types of insulation has been covered.
*E. Mazria The Passive Solar Energy Book, pp. 250-257.
**See Activity 11 "Roof Overhang" in D.O.E. Solar Energy Project-Activities Junior High Science.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 1 hr.

6.2 Building Structural Considerations

6.2.2 Earth-Sheltered Constructions

OBJECTIVES		STRATEGIES
6.2.2.1	Explain the theory of thermal efficiency of subterranean structures.	a. Invite an architect who has designed earth-sheltered structures to talk to the class. b. With post hole digger, dig holes 2, 3, 4 and 5' deep and have class keep log of bottom-of-hole temperatures over a six-month period.* c. Find a person who has lived in an earth-sheltered house and invite him to relate his experiences to the class. d. Display pictures, plans and sections of earth-sheltered designs. e. Have student design a passively-heated earth-sheltered structure. Transparency #34
6.2.2.2	Explain design considerations, such as soil types, drainage and moisture control, load support, etc., peculiar to earth-sheltered structures.	

NOTES:

*Use indoor/outdoor thermometer with separate sensing bulb placed at the bottom of each hold. Fill holes with loose soil and begin recording temperatures so that comparisons can be made.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 45 mins.

6.3 Direct Gain Systems

6.3.1 Windows, Clerestories and Skylights

OBJECTIVES	STRATEGIES
6.3.1.1 Calculate the recommended range of south-facing glass (in square feet) for a 1500 sq. ft. dwelling in a given climate	a. Present data (through lecture, hand-outs, or reading assignments) regarding the heat gain/loss characteristics of windows.
6.3.1.2 Discuss the advantages and disadvantages of north, east and west facing glass area in terms of heat gain and loss during a heating season.	b. Explain procedure for calculating heat gain through south-facing windows. Transparency #35.
6.3.1.3 Describe or define a direct gain system.	c. Assign classroom or homework exercises in calculating heat gain/loss.*
	d. Have class keep a log of temperatures recorded at different facing windows at different times of the day and seasons of the year.

NOTES:

*1. Have students calculate heat loss of their own home.

*2. Have students calculate heat gain through south-facing glass in their homes.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 45 mins.

6.3 Direct Gain Systems

6.3.2 Masonry Heat Storage

OBJECTIVES	STRATEGIES
6.3.2.1 Discuss the use of masonry thermal storage, stressing the following factors: location, size, and distribution of thermal mass.	a. Assign reading material on masonry thermal storage followed by illustrated lecture on same subject. Transparency #36 and #37.
6.3.2.2 Describe the difference in heat transfer properties of water and masonry in a direct gain system.	b. Display of drawings and data of masonry masses of varying thermal efficiency.
6.3.2.3 Locate the recommended figures and calculate the amount of double glazed masonry thermal storage wall for an 800 sq. ft. dwelling area.	c. Classroom and/or homework exercises in calculating masonry thermal mass sizes to meet building design needs.*

NOTES:

*See E. Mazria The Passive Solar Energy Book, pp. 136-143.
Also, Activity #4,"Energy Storage" in D.O.E. Solar Energy Project-Activities Junior High School Science.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.3 Direct Gain Systems

6.3.3 Interior Water Storage

OBJECTIVES	STRATEGIES
6.3.3.1 Recall the amount of water (cubic feet or gallons) recommended for each square foot of solar window.	a. Lecture on heat storage capacities of water.
6.3.3.2 Describe the difference in heat transfer properties of water and masonry in a direct gain system.	b. Classroom and/or homework exercise in calculating water heat storage capacity.
6.3.3.3 Calculate number of BTU's that one cubic foot of water can store with a 50 degree temperature rise.	c. Keep an hourly log of interior temperatures of cubic feet of water and 2 cubic feet of masonry that have been heated to a temperature of 150 degrees.

NOTES:

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.4 Indirect Gain Systems

6.4.1 Mass Trombe Wall

OBJECTIVES	STRATEGIES
6.4.1.1 Describe or define a mass Trombe wall system and explain how it functions.	a. Use overhead projector to illustrate lecture on mass Trombe wall systems. Transparency #38.
6.4.1.2 Calculate the approximate heating contribution of a mass Trombe wall system to the heating requirements of a particular structure.	b. Display plans and sections of buildings incorporating mass Trombe wall system.
6.4.1.3 Incorporate a mass Trombe wall system in the design of a dwelling.	c. Lecture on calculation of potential heating contribution of mass Trombe walls.
	d. Classroom and/or homework practice in designing buildings that incorporate mass Trombe wall systems.

NOTES:

*See E. Mazria The Passive Solar Energy Book pp. 159-171.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.4 Indirect Gain System

6.4.2 Water Trombe Wall

OBJECTIVES	STRATEGIES
6.4.2.1 Describe or define a water Trombe wall system and explain how it functions.	a. Give an illustrated lecture on water Trombe wall systems. Transparency #39.
6.4.2.2 Calculate the approximate heating contribution of a water Trombe wall system to the heating requirements of a particular structure.	b. Display plans and sections of building incorporating water Trombe walls.
6.4.2.3 Incorporate a water Trombe wall system in the design of a dwelling.	c. Plan a field trip to a structure incorporating a water Trombe wall system.
	d. Lecture on calculation of potential heating contribution of water Trombe wall system.
	e. Devise a classroom and/or homework assignment in designing buildings that incorporate water Trombe wall systems.

NOTES:

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.4 Indirect Gain System

6.4.3 Roof Pond Systems

OBJECTIVES	STRATEGIES
6.4.3.1 Describe the way a roof pond system functions to heat and/or cool a building. 6.4.3.2 Describe critical design considerations for roof pond systems. 6.4.3.3 Incorporate a roof pond system in the design of a building.	a. Illustrated lecture covering roof pond systems. Transparency #40. b. Display plans and sections of buildings incorporating roof pond systems. c. Field trip to building incorporating roof pond system. d. Invite outside expert to lecture on roof pond systems. e. Classroom and/or homework exercise in designing dwellings incorporating roof pond systems.

NOTES:
Reference: E. Mazria The Passive Solar Energy Book, pp. 187-199.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 45 mins.

6.5 Isolated Gain Systems

6.5.1 Sunspace

OBJECTIVES	STRATEGIES
6.5.1.1 Describe the basic characteristics and functioning of a sunspace (greenhouse) system.	a. Illustrated lecture on sunspace systems.*
6.5.1.2 Calculate the potential heat contribution of a sunspace system.	b. Display of plans and sections of sunspace systems.
6.5.1.3 Design a structure incorporating a sunspace system.	c. Field trip to building incorporating a sunspace system.
	d. Classroom/homework exercise on calculating the potential of a particular sunspace system.
	e. Classroom/homework exercise on designing structure incorporating sunspace system.

NOTES:

See Northeastern Solar Energy Education Center Solar Energy Adult Education for suitable transparency masters.

MAJOR CONCEPT 6.0 PASSIVE SYSTEM DESIGN **TIME** 30 mins.

6.5 Isolated Gain Systems

6.5.2 Thermosiphon Systems

OBJECTIVES	STRATEGIES
6.5.2.1 Describe the basic elements of design and explain the functioning of a thermosiphon system.	a. Illustrated lecture on thermosiphon systems.
6.5.2.2 Explain how a thermosiphon system is controlled to prevent excessive heat gain/loss.	b. Display of plans and sections of thermosiphon systems.*
6.5.2.3 Be able to design a thermosiphoning system using either air or water as the heat transfer medium.	c. Construct a working model of a thermosiphon system.
	d. Classroom/homework exercise in designing a thermosiphon system.

NOTES:

*AIA Research Corp, U.S. Department of Energy, A Survey of Passive Solar Buildings.

CONCEPT 7.0

ENERGY CONSERVATION

MAJOR CONCEPT 7.0 - ENERGY CONSERVATION

Educational Objectives

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

7.1.1.1 identify areas of infiltration in a single family dwelling.

7.1.1.2 recommend three ways to reduce infiltration heat loss in a single family dwelling.

7.1.2.1 identify areas of conduction heat loss in a single family dwelling.

7.1.2.2 recommend three ways of reducing conductive heat loss in a single family dwelling.

7.2.1.1 identify five samples of different types of insulation and list one advantage and one disadvantage of each type.

7.2.1.2 recall the R-value of these five examples per inch.

7.2.1.3 identify uses for various insulation types.

7.3.1.1 list at least five life-style changes which could be made to save energy.

MAJOR CONCEPT 7.0 ENERGY CONSERVATION **TIME** 30 mins

7.1 Heat Loss

7.1.1 Infiltration Losses

OBJECTIVES	STRATEGIES
7.1.1.1 Identify areas of infiltration in a single family dwelling. 7.1.1.2 Recommend three ways to reduce infiltration heat loss in a single family dwelling.	a. Discuss areas of infiltration heat loss. Emphasize windows, doors, and areas where construction materials change (i.e. foundation masonry to wood).* b. Illustrate methods of correcting infiltration loss areas such as caulking and weatherstripping. c. Show students three types of caulking. Discuss advantages and disadvantages of each. d. Demonstrate use of caulking gun--two sizes. e. Have each student find at least two different specific sources of infiltration heat loss in the school. Compile list and send to administration.

NOTES:

*Two excellent sources for transparency masters on weatherization are: Northeast Solar Energy Education Center Solar Energy Adult Education and DOE, Project Retrotech.

MAJOR CONCEPT 7.0 ENERGY CONSERVATION TIME 30 mins.

7.1 Heat Loss

7.1.2 Conduction

OBJECTIVES	STRATEGIES
7.1.2.1 Identify areas of conduction in a single family dwelling.	a. Discuss R-values of various building materials.
7.1.2.2 Recommend three ways of reducing conductive heat loss in a single family dwelling.	b. Figure heat loss of a residence for class. Have students determine heat loss of same structure if six inches of additional insulation are added to the ceiling. Then have students calculate the heating costs of both cases for entire heating season.
	c. Have students determine the heat loss in BTU/hr for their own homes. Have students make recommendations for insulation upgrading if needed.*

NOTES:

*See Activity #39"Effects of Insulation on Home Heating Costs" in DOE Solar Energy Project, General Solar Topics.

MAJOR CONCEPT 7.0 ENERGY CONSERVATION **TIME** 30 mins

7.2 Insulation

7.2.1 Types and Applications

OBJECTIVES	STRATEGIES
7.2.1.1 Identify five samples of different types of insulation and list one advantage and one disadvantage of each type. 7.2.1.2 Recall the R-value of these five examples per inch. 7.2.1.3 Identify uses for various insulation types.	a. Discuss the properties of various insulation materials. b. Show students actual samples of the following insulations: 6" fiberglass, 3½" fiberglass, Rockwool, Cellulose, Vermiculite, Urethane, Styrofoam. c. Have local insulation contractor speak to class about insulation. d. Have local insulation "foam in place" contractor speak to class. e. Visit house construction site where insulating is underway. f. Have students experiment with R-values of different types/ thicknesses of insulation.*

NOTES:

*See activity #9 "Insulation: Can it Keep Heat In and Out?" in DOE Solar Energy Project-Junior High Science.

MAJOR CONCEPT 7.0 ENERGY CONSERVATION **TIME** 30 mins.

7.3 Life Style

7.3.1 Life-Style Changes

OBJECTIVES	STRATEGIES
7.3.1.1 List at least five life-style changes which could be made to save energy.	a. Class discussion of some typical life-style that could easily be made to cut home heating costs. b. Have someone who has moved from a traditional home to a passive solar home address the class and discuss life-style changes they have made to save energy. c. Show 16 mm D.O.E. film "Sun Builders." After film, discuss evident life-style changed called attention to in the film. d. Have students role-play to point out differences and life-style implications between the present and the past when energy was relatively inexpensive. (See appendix.) e. Visit solar home or other solar installation site. Talk with owner about life-style adaptations. f. Have a warm clothing fashion show (P.J.'s to Parkas). g. Have students discuss what they perceive life will be like in the year 2000 as a result of the energy problems of today.

NOTES:

CONCEPT 8.0

OCCUPATIONS

MAJOR CONCEPT 8.0 - OCCUPATIONS IN SOLAR SPACE HEATING

Educational Objectives

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

8.1.1 describe at least two sales occupations in the field of solar heating.

8.2.1 describe at least two design positions within the field of solar heating.

8.3.1 describe the operations required of a system installer.

8.4.1 describe the operations required of an electrician who installs solar control systems.

8.5.1 describe the operations required of the service and maintenance technician.

MAJOR CONCEPT 8.0 OCCUPATIONS IN SOLAR SPACE HEATING **TIME** 30 mins.

8.1 Sales

OBJECTIVES	STRATEGIES
8.1.1 Describe at least two sales occupations in the field of solar heating.	a. Ask a salesperson from a manufacturer or distributor of solar heating products to speak to the class about the: 1) opportunities for employment in the solar sales field, 2) working conditions, and 3) future advancement potential, and 4) necessary education and experience.* b. Discuss sales opportunities in the solar heating field with attention to items one through four in strategy "a."

NOTES:

*Reference for occupations: O'Conner, Devin. Solar Energy Task Force Report Technical Training Guidelines. Solar Energy Research Institute. 1979, and Gwazda E., et al, Energy Occupation Handbook.

It is suggested that, in order to explore effectively occupations in the field of solar heating in the time permitted, guests discussing various occupations should be scheduled throughout the entire unit time frame. Also for independent study, students could complete Activity #38 "Careers in Solar Energy" in DOE Solar Energy Project-General Solar Topics.

MAJOR CONCEPT 8.0 OCCUPATIONS IN SOLAR SPACE HEATING **TIME** 30 mins.

8.2 Designer

OBJECTIVES	STRATEGIES
8.2.1 Describe at least two design positions within the field of solar heating.	a. Have a designer of solar equipment and/or solar heating systems discuss his/her occupation and related occupations with the class. Attention could be given to: 1) background and education required, 2) employment opportunities, 3) salaries, and working conditions, and 4) future advancement potential. b. Discuss the different design occupations within the field of solar heating including system designers and component designers.

NOTES:

MAJOR CONCEPT 8.0 OCCUPATIONS IN SOLAR SPACE HEATING **TIME** 30 mins.

8.3 Installer

OBJECTIVES	STRATEGIES
8.3.1 Describe the operations required of a system installer.	a. Have a system installer discuss his position with students. Attention should be given to: 1) background and education needed, 2) specific skills required, 3) employment opportunities, and 4) salaries and working conditions. b. Discuss position of solar system installer with class and emphasize the points above.

NOTES:

MAJOR CONCEPT 8.0 OCCUPATIONS IN SOLAR SPACE HEATING TIME 30 mins.

8.4 Electrician

OBJECTIVES		STRATEGIES
8.4.1	Describe the operations required of an electrician who installs solar control systems.	a. Ask an electrician to discuss the operations he performs including: 1) opportunities for employment, 2) education and background necessary, 3) salary and working conditions, and 4) advancement opportunities. b. Discuss the role of the electrician in the installation of new and retrofitted solar systems.

NOTES:

MAJOR CONCEPT 8.0 OCCUPATIONS IN SOLAR SPACE HEATING **TIME** 30 mins.

8.5 Service and Maintenance Technician

OBJECTIVES		STRATEGIES
8.5.1	Describe the operations required of the service and maintenance technician.	a. Have a solar service and maintenance technician speak to class about: 1) education and background needed, 2) employment opportunities, 3) salary and working conditions, 4) future advancement potential, and 5) duties.

NOTES:

EVALUATION

EVALUATION OF COMPETENCIES

Time did not permit the development of an extensive evaluation plan for this instructional package. However, a chart for evaluating the very basic competencies that a student should acquire through instruction has been developed. The chart in the form of a profile can be used as a checklist to show the student's performance level in several basic competencies. The chart, which appears on the next page, lists the basic competencies in the left hand column. The columns on the right relate to the performance level obtained by the student for each competency. The teacher and/or the student can select the performance level for each competency using one of the following keys:

If the competency is a manipulative skill, one of the following numbered columns is checked:

0 = Unacceptable
1 = Introduced
2 = Requires Supervision
3 = Works Independently

If the competency is a cognitive skill (e.g. understanding information) one of the following numbered columns is checked:

0 = Unacceptable
1 = Average
2 = Above Average
3 = Superior

A variety of evaluation devices will need to be developed by the teacher to provide the information necessary for accurately completing the profile chart. These devices will vary with individual teachers, but will probably include written tests, manipulative performance tests, teacher observations and student self-evaluations to name a few.

Although the task of constructing these devices has been left up to the individual teacher, project staff felt that this task will be facilitated by referring to the educational objectives listed for each third level concept. The objectives have been written in behavioral terms and provide a definitive statement regarding what the student should know or be able to do. Written in this fashion, the objectives should provide the teacher with the primary information needed for the development of various evaluation instruments.

BASIC COMPETENCY PROFILE CHART
Solar Space Heating

Competencies	*	Performance Level 0	1	2	3
1. List historical developments.					
2. Define the solar constant.					
3. List variations affecting solar radiation.					
4. Explain collector mounting location options.					
5. Describe life-cycle cost considerations.					
6. Calculate storage mass.					
7. Describe various types of collectors.					
8. Determine advantages and disadvantages of various systems.					
9. Diagram an air and a liquid system.					
10. Explain function of various components.					
11. Describe interfacing of back-up and solar.					
12. Explain installation procedures.					
13. Describe installation standards.					
14. Explain various service procedures.					
15. Use troubleshooting charts.					
16. Explain factors affecting home site selection.					
17. Explain passive home characteristics.					
18. Describe passive systems for new construction and retro-fitting.					
19. Describe several ways of making a house energy efficient.					
20. List several new occupations created by the solar industry.					

*KEY

If a Manipulative Skill, Check	If Information, Check
0 = Unacceptable	0 = Unacceptable
1 = Introduced	1 = Average
2 = Requires Supervision	2 = Above Average
3 = Works Independently	3 = Superior

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Cooper-Solar Ed Series ($130/set)
Solar Energy Availability, SL-10B (30 Slides
Flat Plate Solar Collectors, SL-10C (60 slides)
Energy Storage, SL-10D (25 slides)
Concentrating Solar Collectors, SL-10E (30 slides)
Measurement and Control Systems, SL-10F (25 slides)
Buildings and Passive Systems, SL-10G (30 slides)
Available from The Copper Solar-Ed. Co., Woodbridge, Ct. 06525

DOE 16mm Films (Free loan.)

Here Comes the Sun	15 minutes, Color, 1974
Look to the Sun	12 minutes, Color, 1977
New Mexico Passive Solar Building	14 minutes, Color
Putting the Sun to Work	5 minutes, Color
Solar Energy: The Great Adventure	27 minutes, Color, 1979
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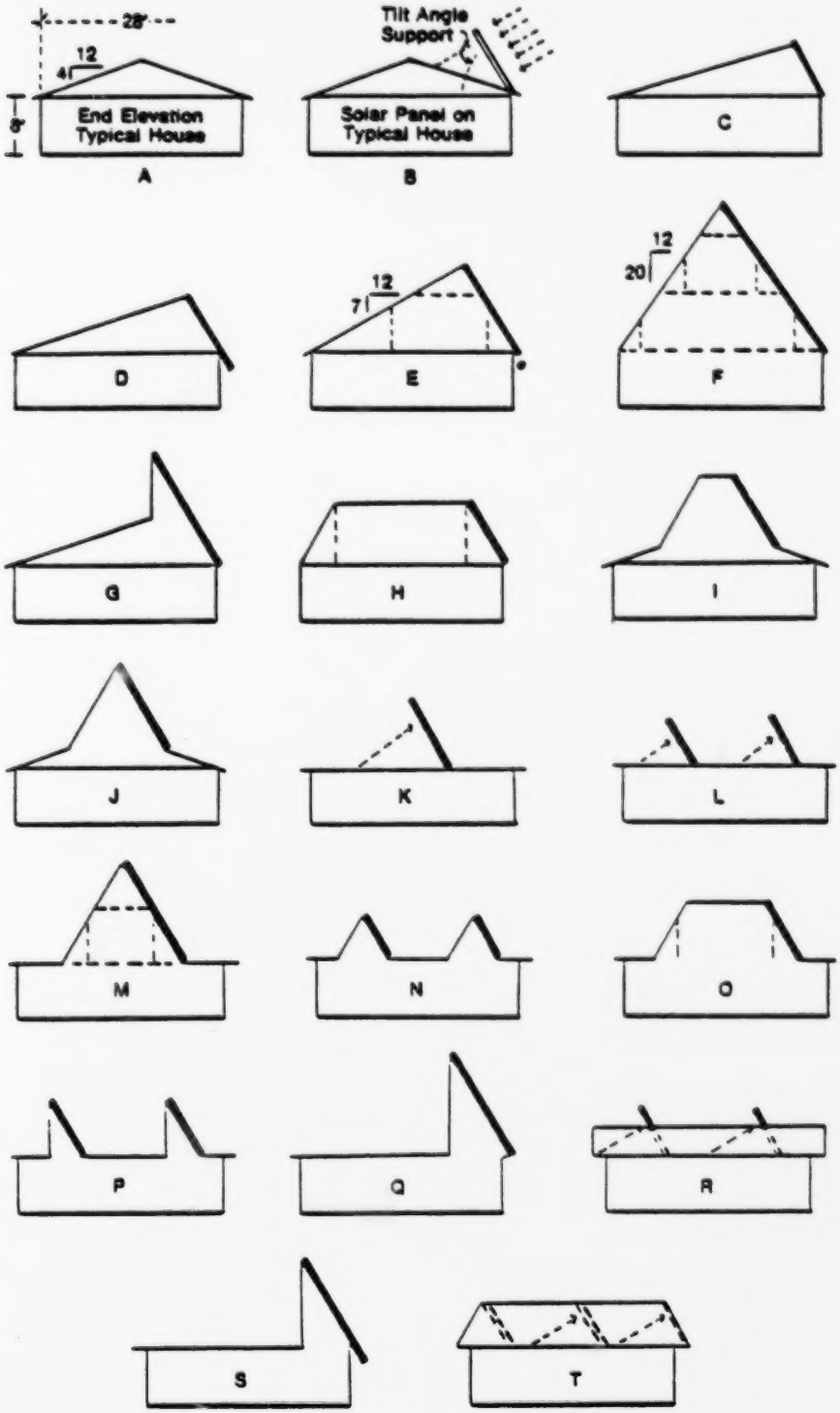
Building Solar: An Introduction to Active System Installation in Homes, Available from Heliotherm, Inc. Lenni, Pa. 19052, (215) 459-9030. Contact Olga McHugh, National Solar Heating and Cooling Information Center, P.O. Box 1607, Rockville, Md. 20850

Special Note: A comprehensive listing of 16mm films, slide programs and video tapes which include the titles listed in this section can be reviewed in the HUD document titled, Solar Energy Audio-Visual Materials (1980 #SS106). Document available from NSHCIC, P.O. Box 1607, Rockville, Md. 20850.

TRANSPARENCY MASTERS

COLLECTOR/ROOF CONFIGURATIONS



Elevations B, C, D, K and L are probably the most economical methods of accommodating a steep tilt angle for solar collectors.

Elevations E, H, M and O are probably the next most economical, recognizing that they provide additional living area on the second floor.

Elevations I, J, M and possibly O, depending on proportions, must be treated carefully.

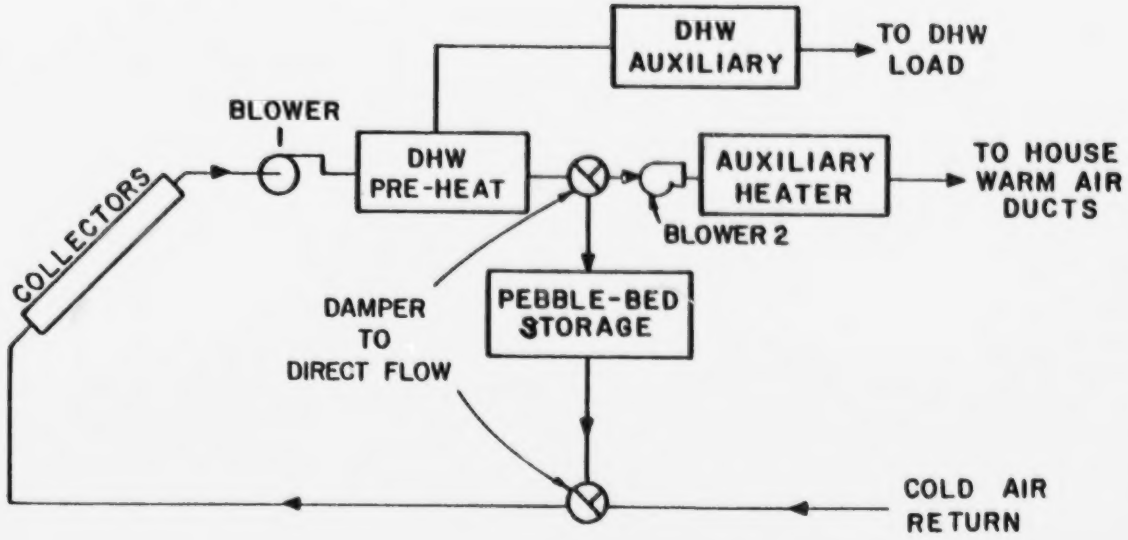
Elevations G, N, P, Q and S are possibilities but are more costly than the first group and especially more costly if clearestory space and/or fenestration are to be provided.

Elevations R and T are of some interest in that they provide a method of hiding the collectors completely, but their comparative cost needs special analysis.

Elevation F is obviously very expensive and only applicable under certain conditions. It does provide a three-story opportunity.

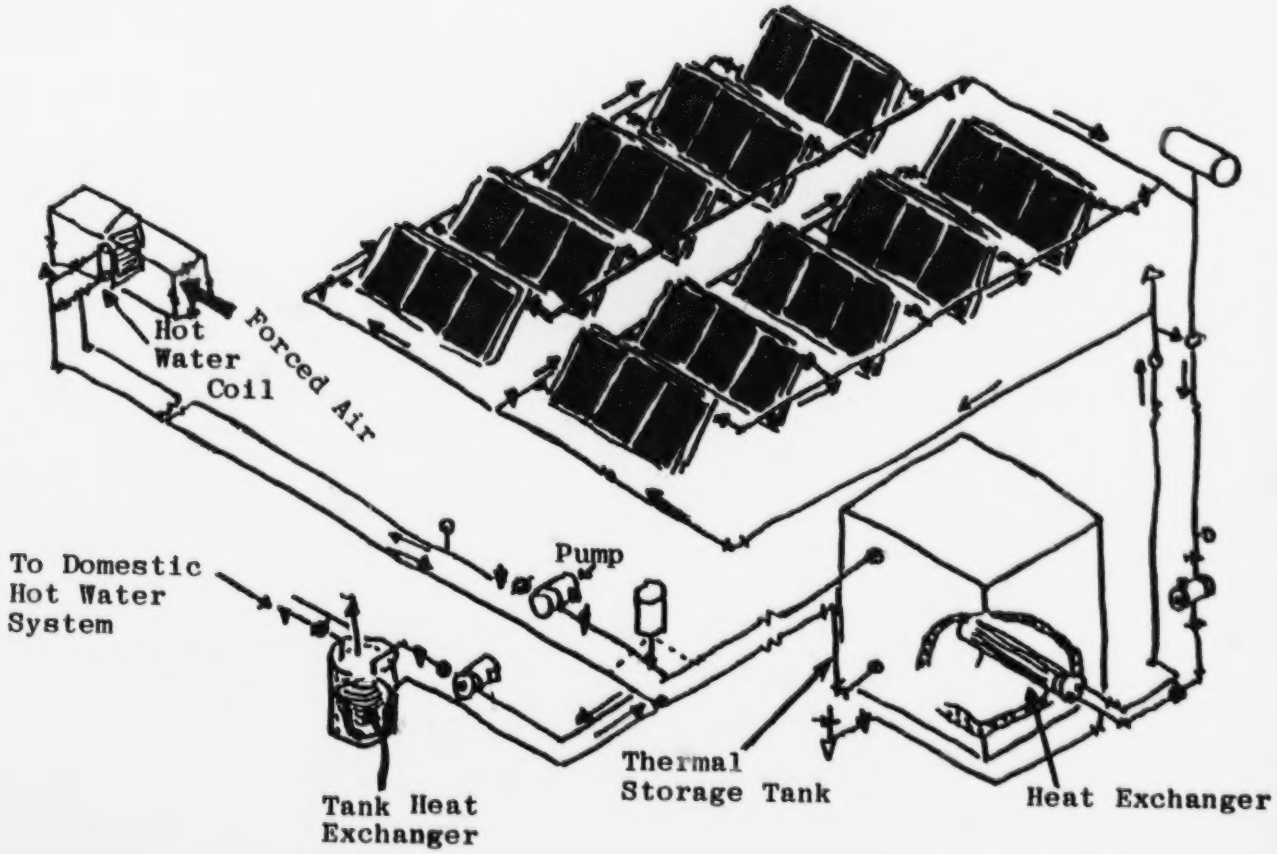
TRANSPARENCY #2

SOLAR AIR SYSTEM



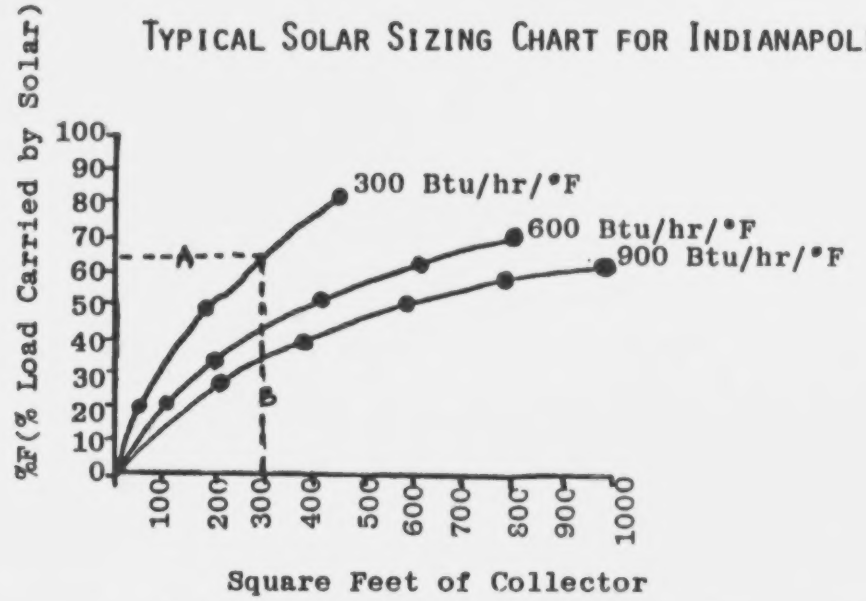
TRANSPARENCY #3

HYDRONIC SOLAR HEATING SYSTEM

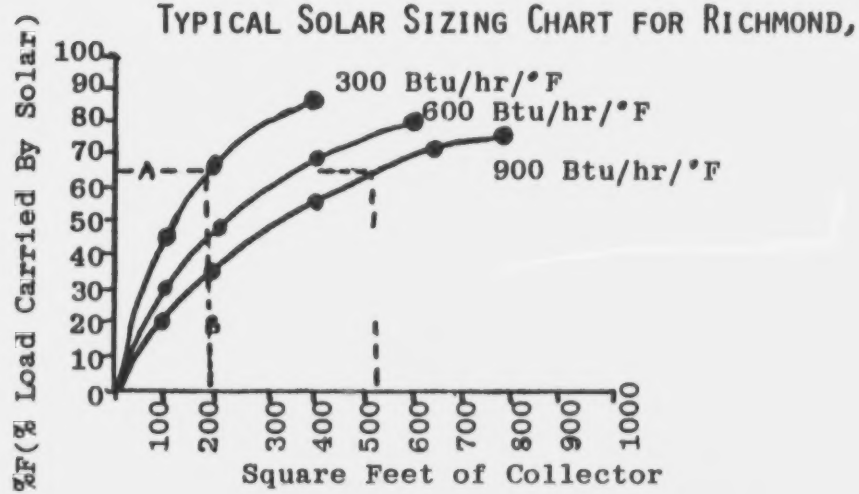


TRANSPARENCY #4

TYPICAL SOLAR SIZING CHART FOR INDIANAPOLIS, INDIANA



TYPICAL SOLAR SIZING CHART FOR RICHMOND, VIRGINIA



Adapted from The Solar Decision Book, Montgomery and Budnick, 1978.

TRANSPARENCY #5

HEAT CAPACITY VALUES

MATERIALS	HEAT CAPACITY	
	BTU/LB °F	BTU/FT 3°F
WOOD	0.6	45
STEEL	.11	54
0.75 TO 1.5 INCH ROCK	0.2	20
WATER	1.0	62

Form **5695**
Department of the Treasury
Internal Revenue Service

Energy Credits

▶ Attach to Form 1040.

1978 ▶

Name(s) as shown on Form 1040 | Your social security number

Residential Energy Credit Computation

Energy Conservation Expenditures. For calendar year 1978 filers, energy conservation property must have been installed after April 19, 1977 and before January 1, 1979. For these expenditures to qualify for the credit, your principal residence must have been substantially completed before April 20, 1977.

(a) Description of item (See instruction B)	(b) Amount	
1 Insulation		
Storm (or thermal) windows or doors		
Caulking or weatherstripping		
Other (specify) ▶		
2 Total (add amounts on line 1)	2	
3 Enter 15% of line 2 (but do not enter more than $300)		3

Renewable Energy Source Expenditures. For calendar year 1978 filers, renewable energy source property generally must have been installed after April 19, 1977 and before January 1, 1979.

(a) Description of item (See instruction C)	(b) Amount	
4 Solar		
Geothermal		
Wind		
5 Total (add amounts on line 4)	5	
6 Enter 20% of line 5 (but do not enter more than $2,000)		6
7 Enter 10% of line 5 (but do not enter more than $200)		7
8 Total (add lines 3, 6, and 7—if less than $10, enter zero here and on line 10 below)		8
9 Limitation:		
a Enter tax from Form 1040, line 37	9a	
b Enter total of lines 38 through 44 from Form 1040	9b	
c Subtract line 9b from line 9a (if less than zero, enter zero)		9c
10 Residential energy credit. Enter the smaller of line 8 or line 9c here and on Form 1040, line 48		10

Instructions

A. Who May Claim the Credit.—Calendar year filers must file Form 5695 to claim a credit for energy saving property installed after April 19, 1977 and before January 1, 1979. Even if you installed an item in 1977 (after April 19), you must claim the credit on your 1978 return. Do not file an amended return for 1977.

Taxpayers with fiscal years beginning in 1977 and ending in 1978 may not claim the credit for the 1977–78 tax year. Fiscal year 1978–79 filers may claim the credit by taking into account the period beginning April 20, 1977 and ending on the last day of the tax year.

B. Energy Conservation Property.—Items eligible for the credit are limited to the following:

(1) insulation (fiberglass, cellulose, etc.) for: ceilings, walls, floors, roofs, water heaters, etc.;
(2) exterior storm (or thermal) windows or doors;
(3) caulking or weatherstripping for exterior windows or doors;
(4) a furnace replacement burner which reduces the amount of fuel used;
(5) a device to make flue openings (for a heating system) more efficient;
(6) an electrical or mechanical furnace ignition system which replaces a gas pilot light;
(7) an automatic energy-saving setback thermostat; and
(8) a meter which displays the cost of energy usage.

These items must be installed in or on your principal residence (as defined in instruction E) after April 19, 1977 and before January 1, 1979 and meet the following tests:

(1) you must be the first person to use the item, and
(2) the item can be expected to remain in use for at least 3 years.

C. Renewable Energy Source Property.—Solar and geothermal energy property may be used to heat or cool your residence (or provide hot water). Solar energy property includes equipment (collectors, rockbeds, and heat exchangers) that transforms sunlight into heat or electricity. Geothermal energy property includes equipment that distributes the natural heat in rocks or water. Wind energy property uses wind to produce energy in any form (generally electricity) for residential purposes.

Renewable energy source property must be installed in connection with your principal residence (as defined in instruction E) and meet the following tests:

(1) you must be the first person to use the item, and
(2) the item can be expected to remain in use for at least 5 years.

D. Items That Do Not Qualify for the Credit.—Examples are:

(1) carpeting;
(2) drapes;
(3) wood paneling;
(4) exterior siding;
(5) heat pump;
(6) wood or peat fueled residential equipment;
(7) fluorescent replacement lighting system;
(8) hydrogen fueled residential equipment;
(9) equipment using wind energy for transportation;
(10) expenditures for a swimming pool used as an energy storage medium; and
(11) greenhouses.

E. Principal Residence Rules.—The credit is available only for your principal residence (you may either own it or rent it from another person). It must be the main home occupied by you and your family. A summer or vacation home would not qualify. It must be located in the United States. To qualify for the energy conservation credit, the residence must have been substantially completed before April 20, 1977.

Note: Please get Publication 903, Energy Credits for Individuals, for special rules about principal residences.

F. Amount of Credit.—The amount of the credit is based on the cost of the item. The cost of an energy conservation item includes its original installation. The cost of a renewable energy source item includes labor costs for its onsite preparation, assembly, or original installation.

The maximum credit for energy conservation items is $300 for each residence. The maximum credit for renewable energy source items is $2,200 for each residence.

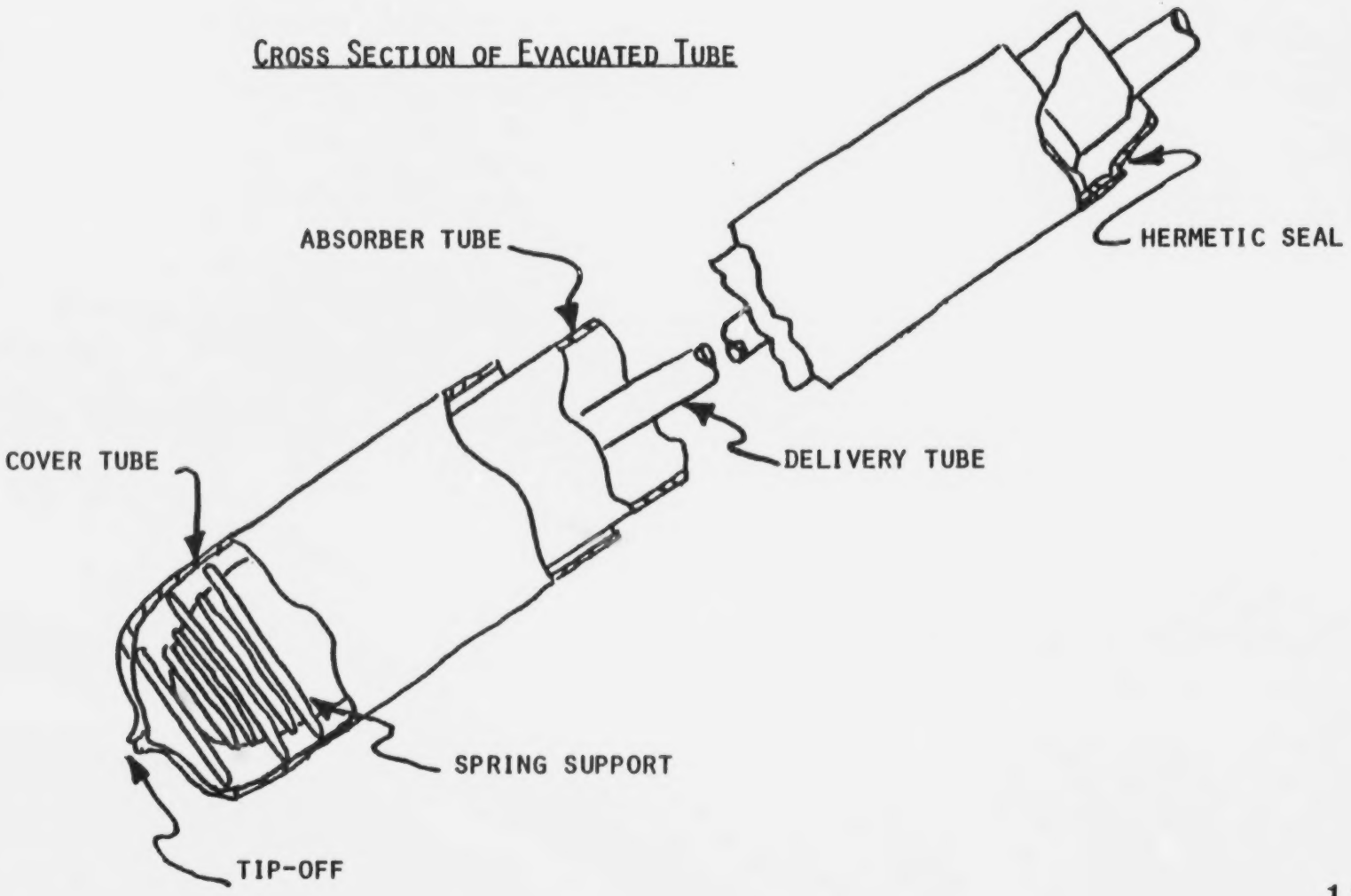
Please get Publication 903 for additional information if you occupied two or more principal residences and made expenditures for energy conservation property or renewable energy source property.

G. Unused Credit Carryover.—If your energy credit for 1978 is more than your tax, you may carry over the unused amount to 1979.

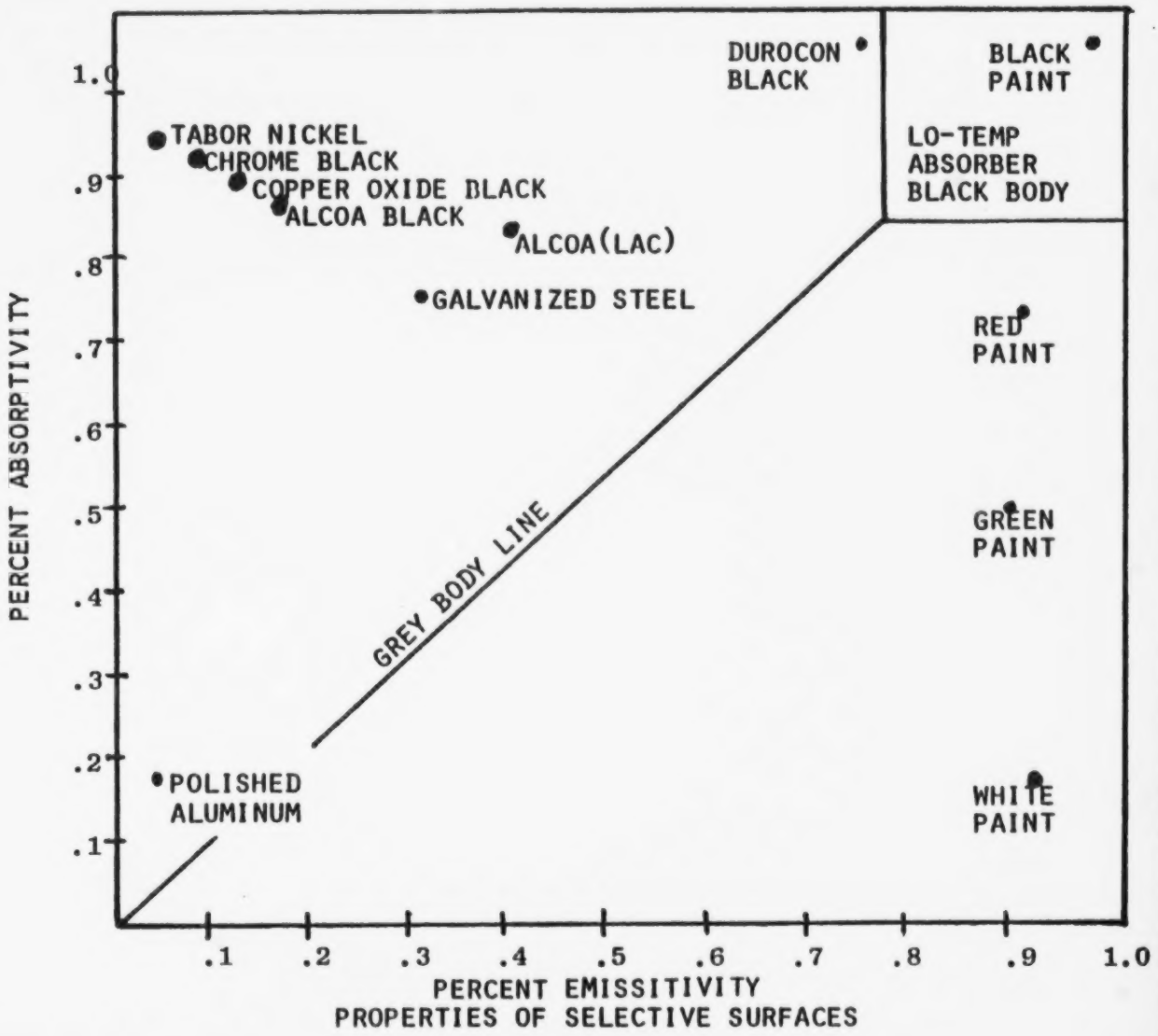
Note: For additional information, get Publication 903, Energy Credits for Individuals.

TRANSPARENCY #7

CROSS SECTION OF EVACUATED TUBE



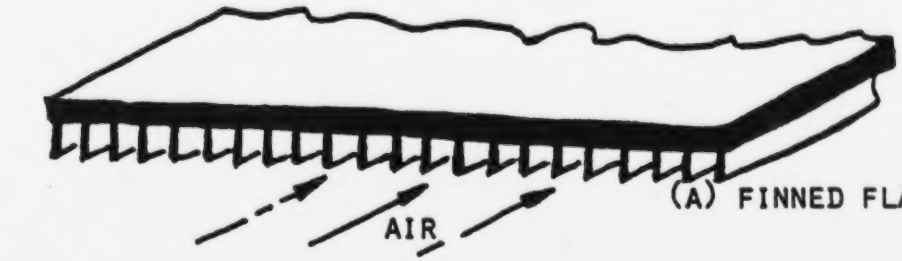
TRANSPARENCY #8



PROPERTIES OF SELECTIVE SURFACES

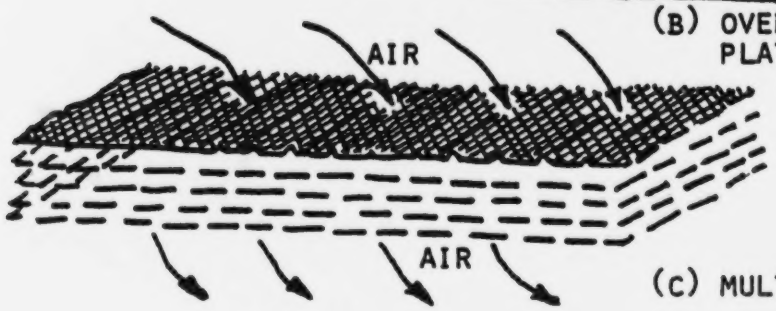
TRANSPARENCY #9

AIR ABSORBER TYPES

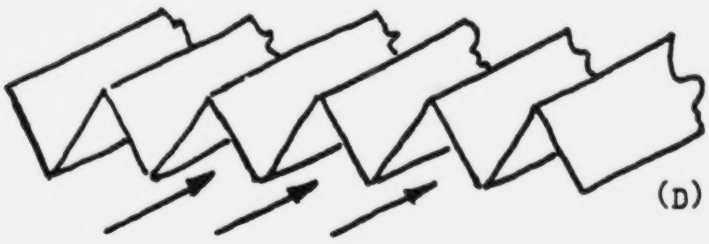


(A) FINNED FLAT PLATE

(B) OVERLAPPED GLASS PLATE

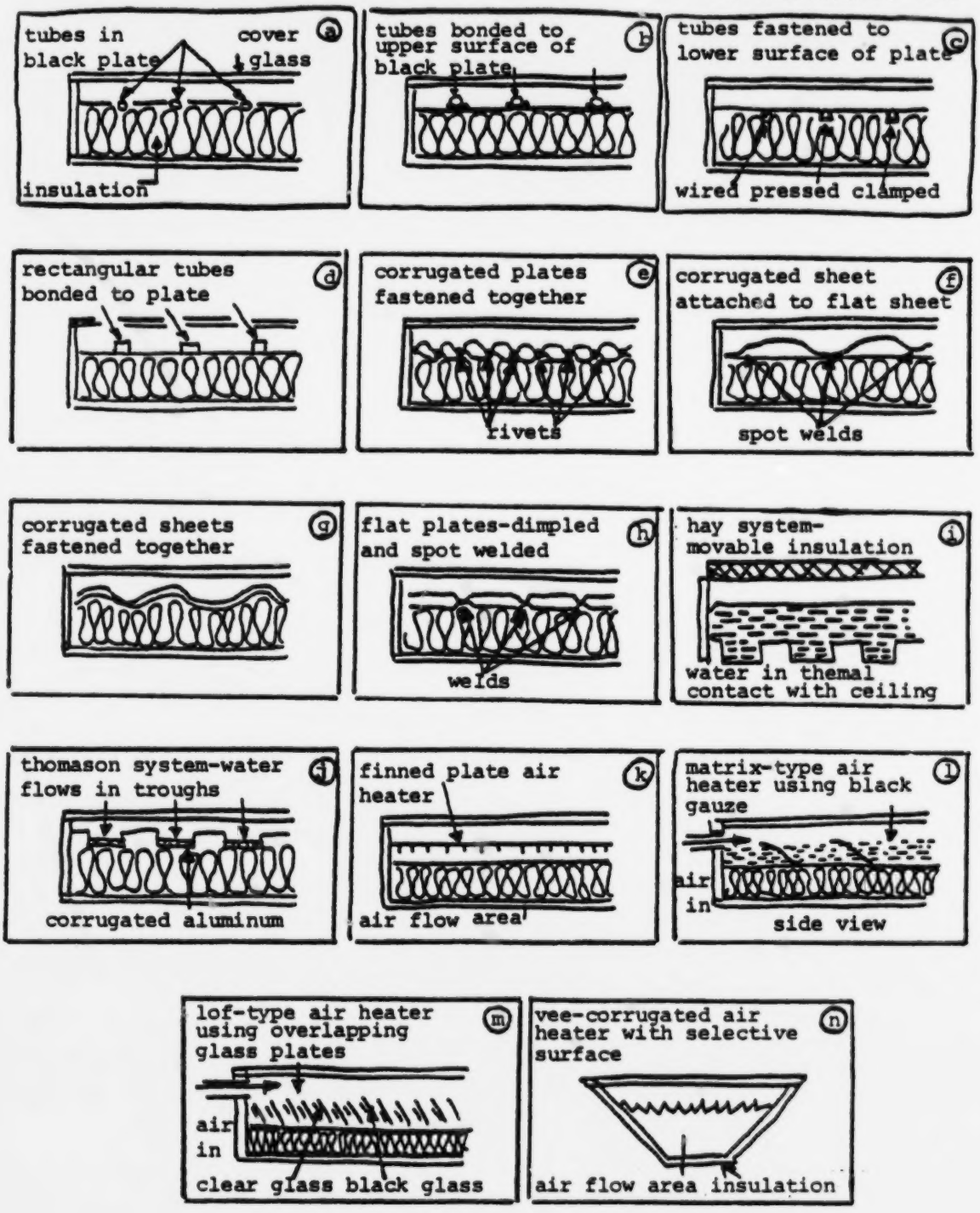


(C) MULTI-GAUZE



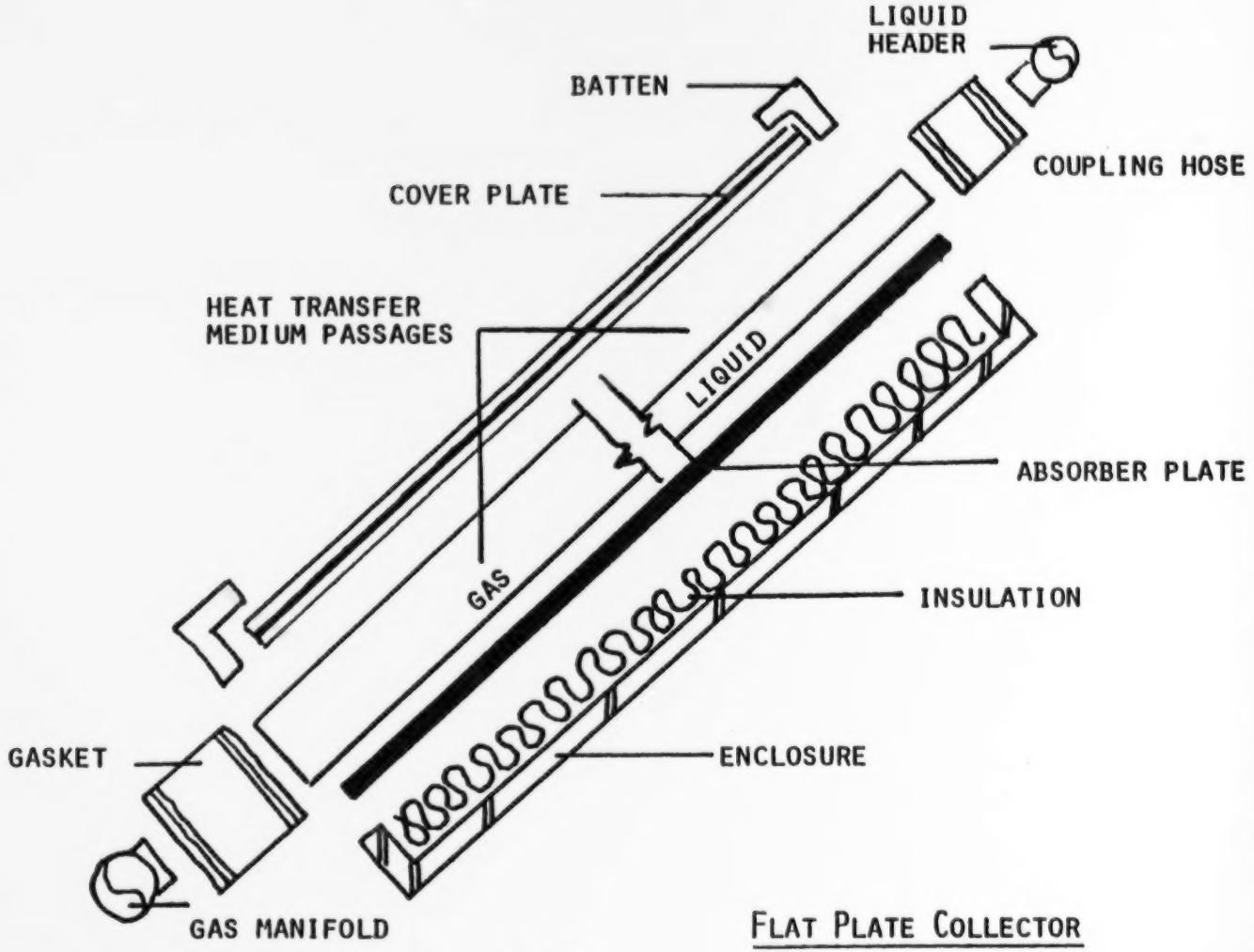
(D) VEE CORRUGATED

(E) POROUS BED



VARIOUS ARRANGEMENTS FOR HEAT EXCHANGERS OF FLAT PLATE COLLECTORS

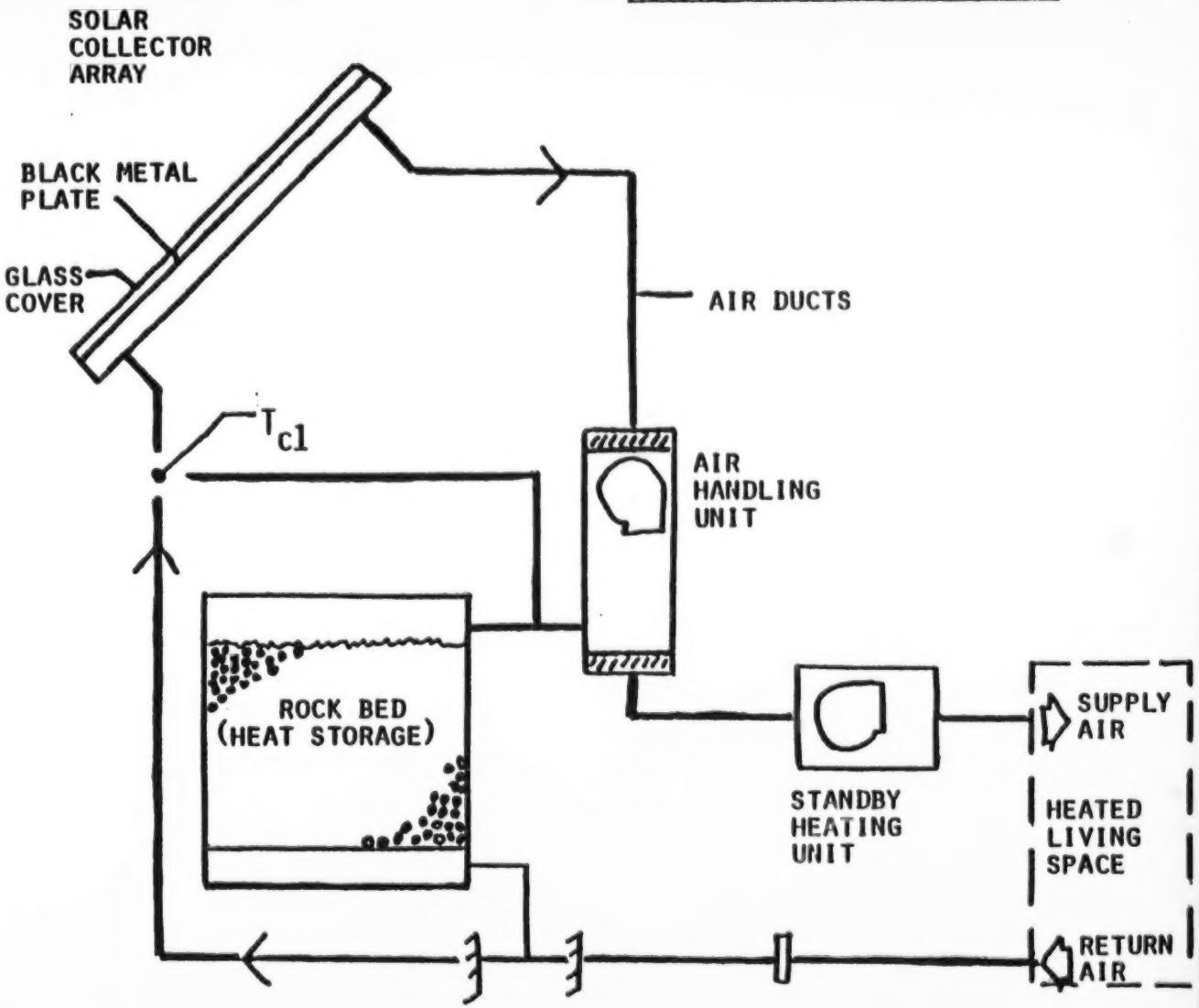
TRANSPARENCY #11



FLAT PLATE COLLECTOR

TRANSPARENCY #12

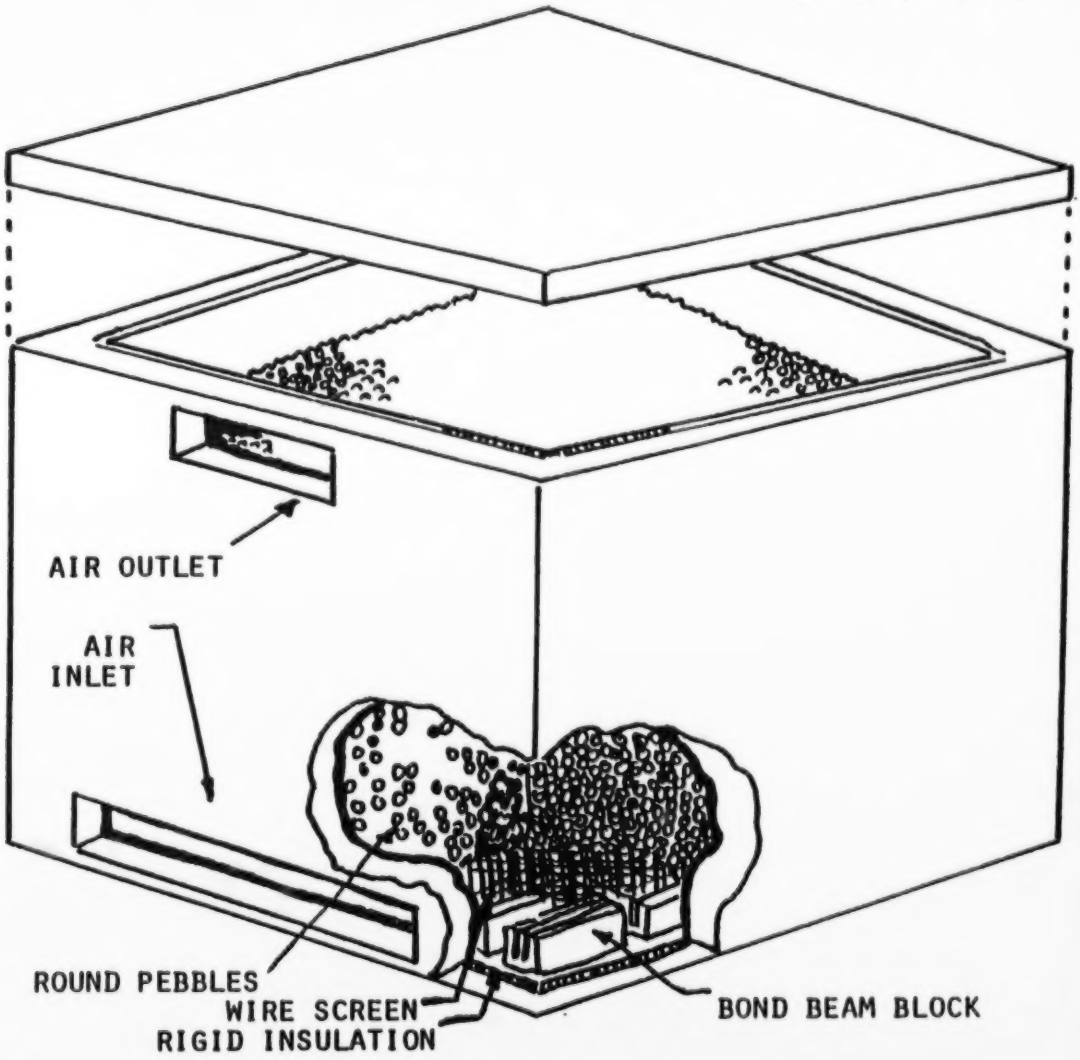
ACTIVE SPACE HEATING SYSTEM



Adapted from Northeast Solar Energy Center, Adult Education Curriculum.

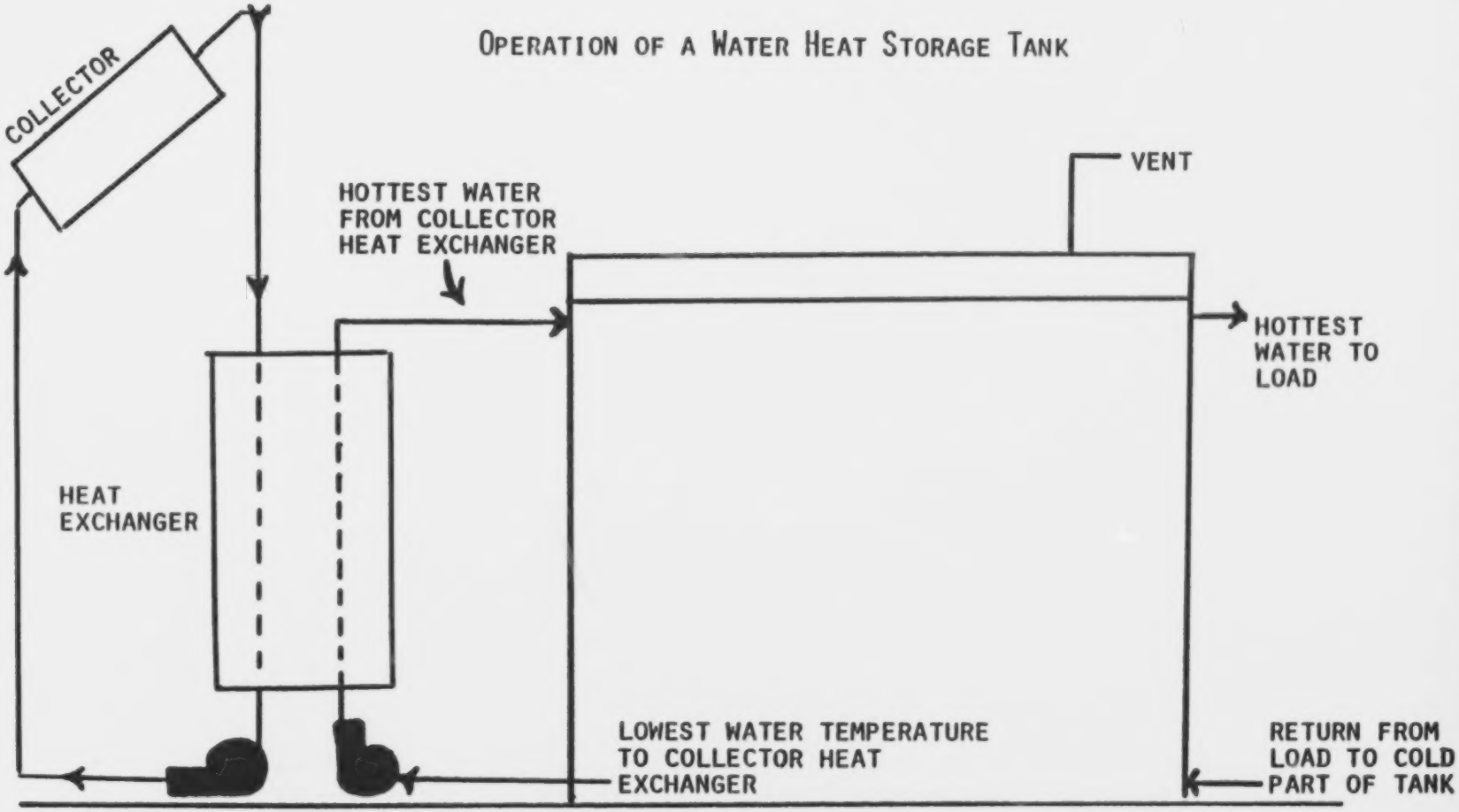
TRANSPARENCY # 13

ROCK BED THERMAL STORAGE
(4' x 4' x 4')



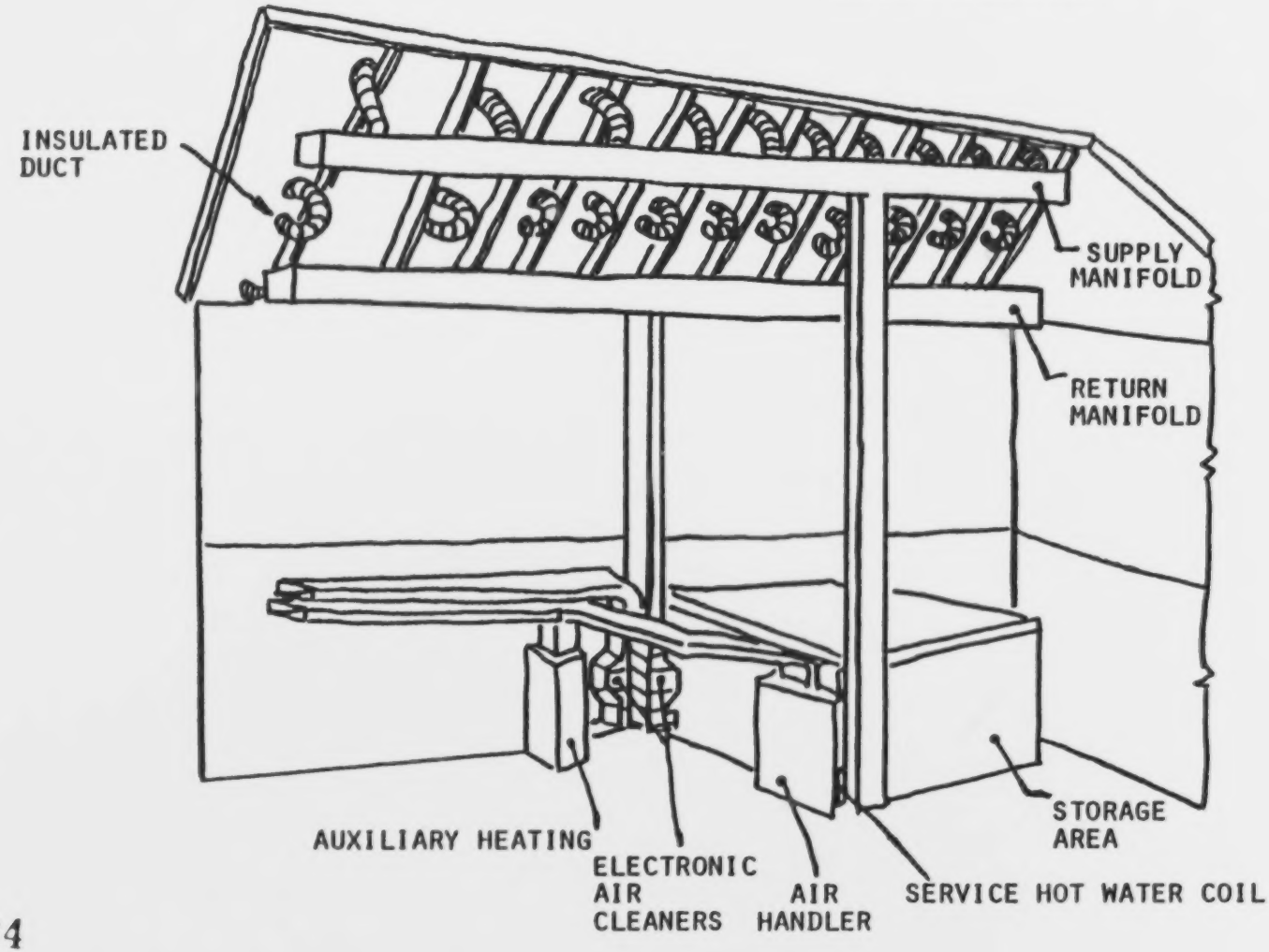
TRANSPARENCY #14

OPERATION OF A WATER HEAT STORAGE TANK

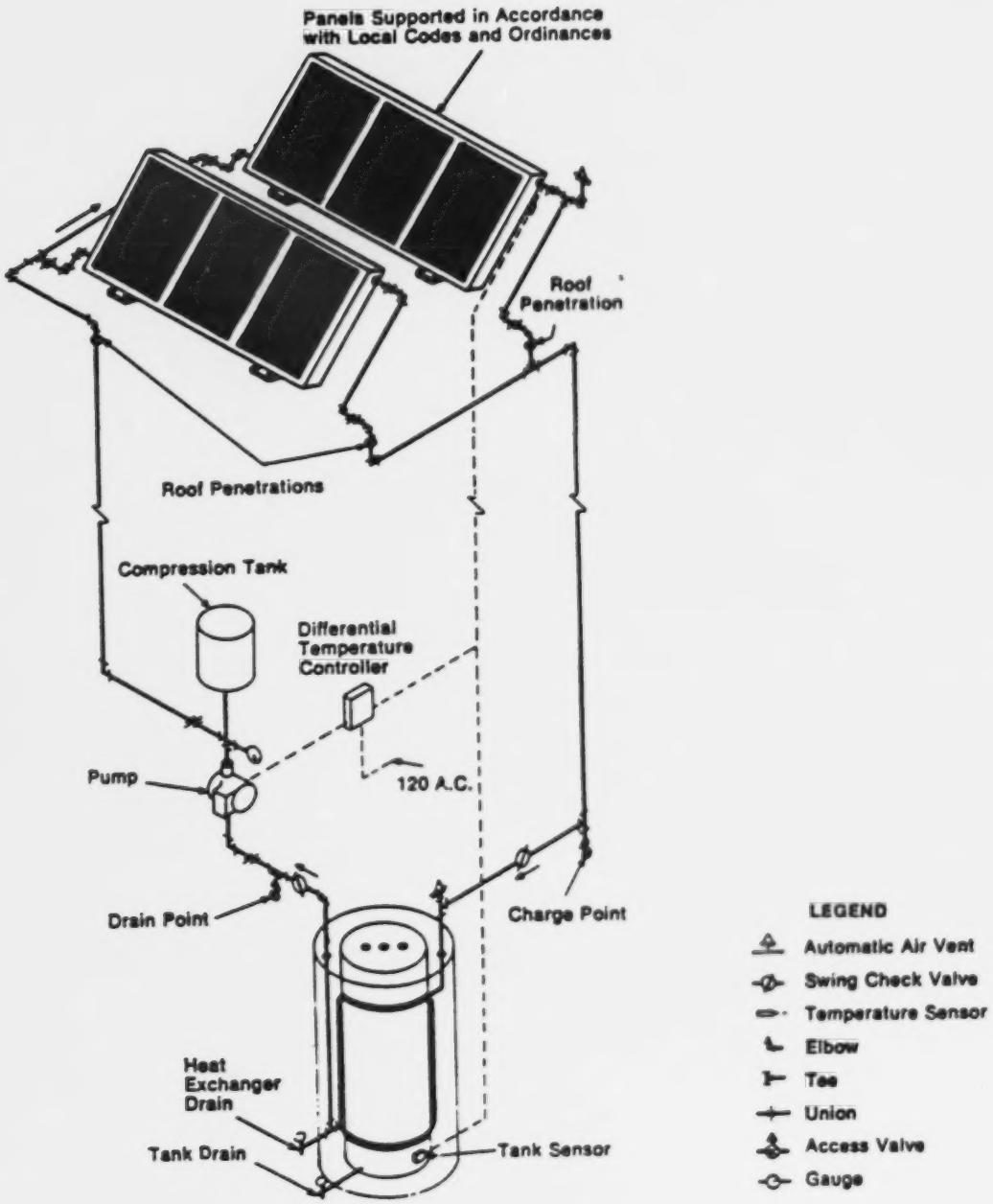

COLLECTOR
VENT
HOTTEST WATER FROM COLLECTOR HEAT EXCHANGER
HOTTEST WATER TO LOAD
HEAT EXCHANGER
LOWEST WATER TEMPERATURE TO COLLECTOR HEAT EXCHANGER
RETURN FROM LOAD TO COLD PART OF TANK

TRANSPARENCY #15

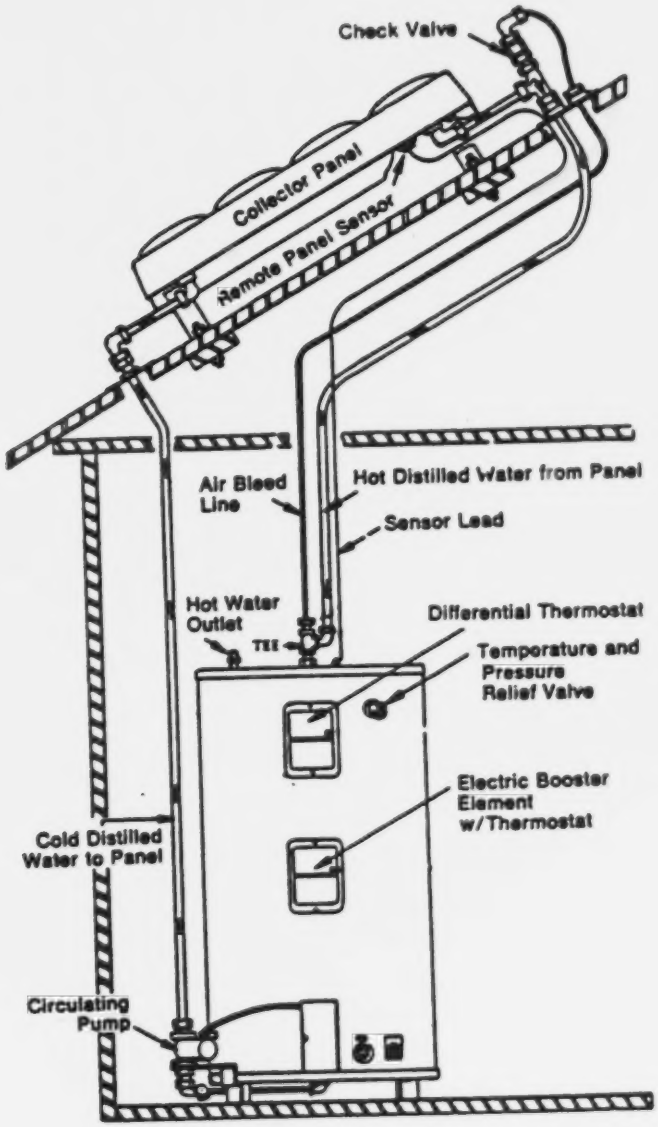
AIR SOLAR SYSTEM



PIPING ARRANGEMENT FOR A CLOSED-LOOP SYSTEM

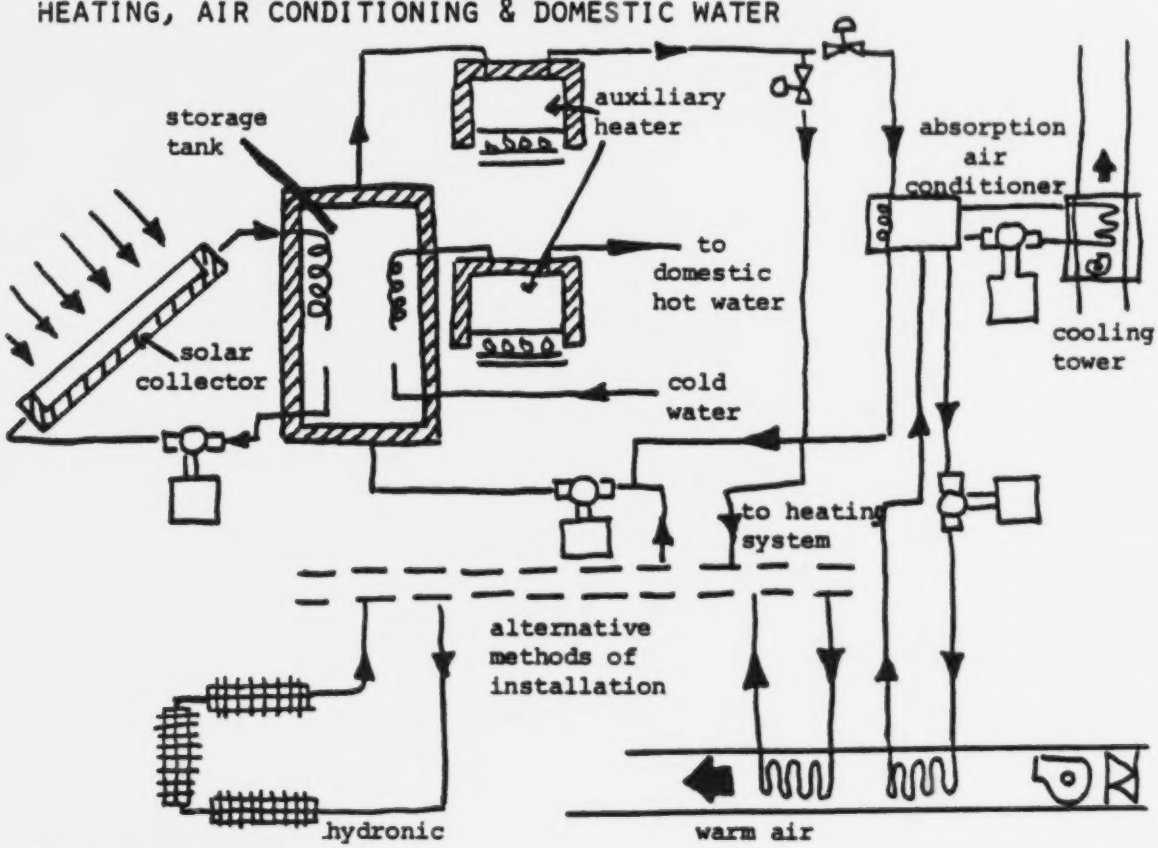


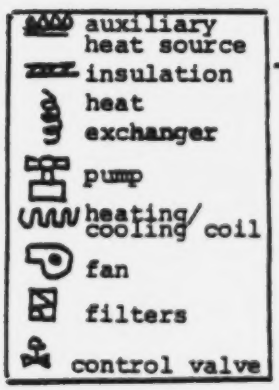
PIPING ARRANGEMENT FOR A DRAIN-DOWN CLOSED-LOOP SYSTEM



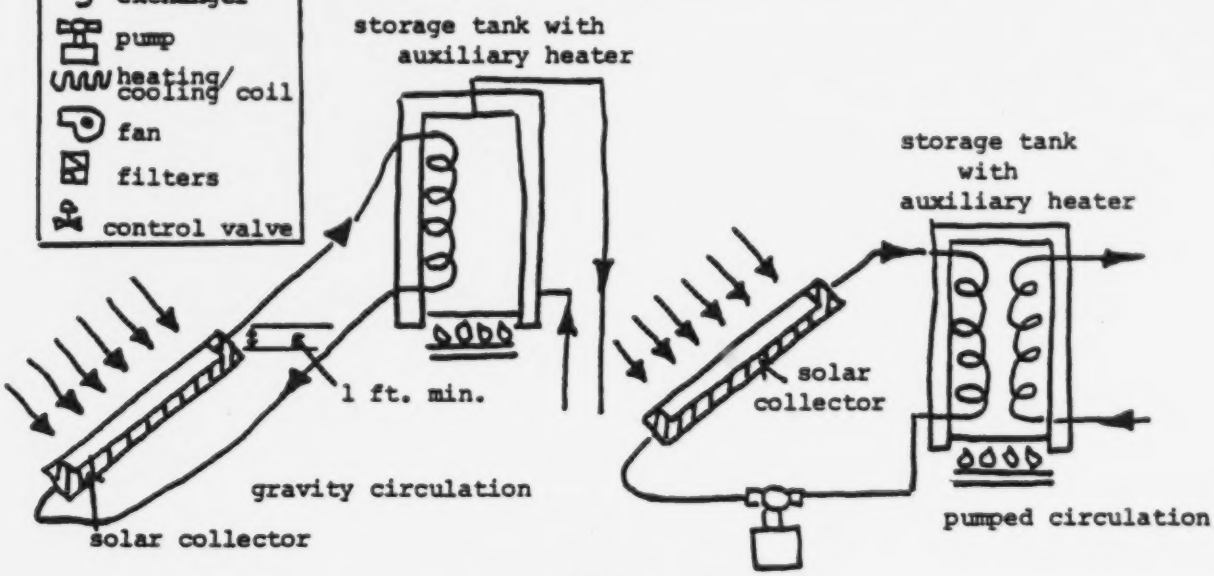
PIPING SYSTEM DESIGN

HEATING, AIR CONDITIONING & DOMESTIC WATER

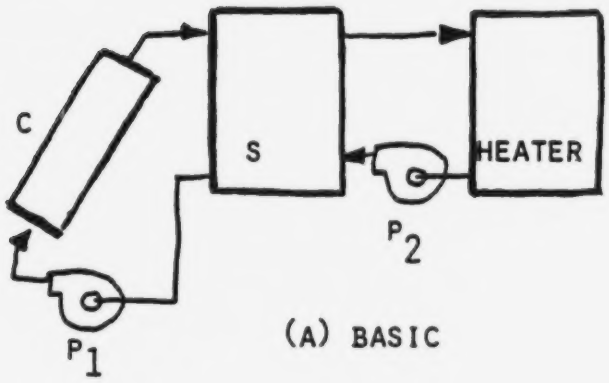




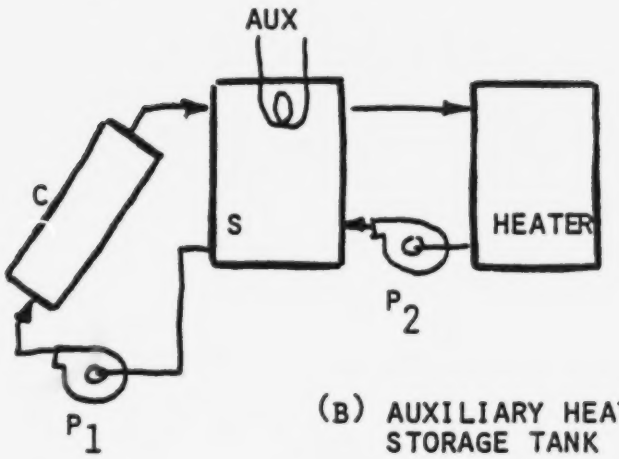
DOMESTIC WATER HEATING



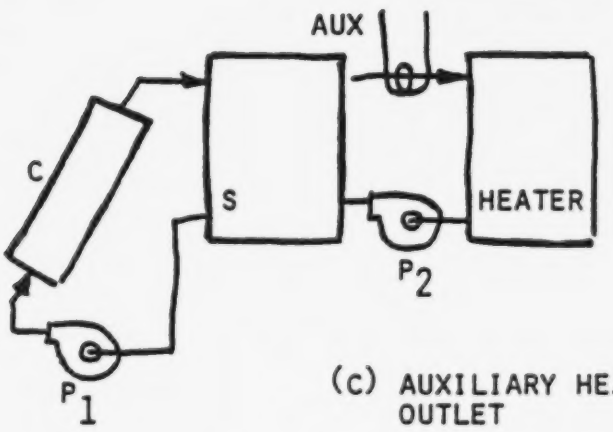
SPACE HEATING CONCEPTS



(A) BASIC

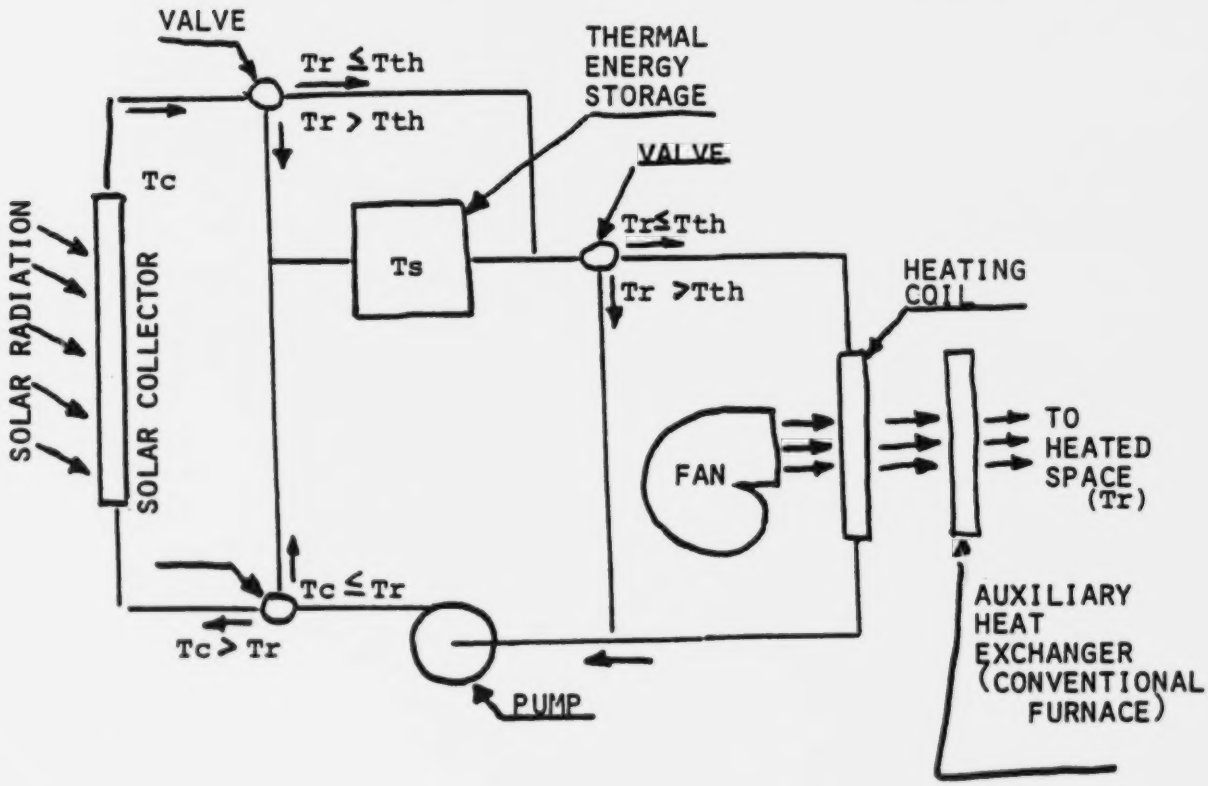


(B) AUXILIARY HEATING IN STORAGE TANK



(C) AUXILIARY HEATING IN OUTLET

SOLAR HEATING AND THERMAL ENERGY STORAGE SYSTEM DESIGN



Tc = Collector temperature

Tr = Room temperature

Ts = Thermal energy storage temperature

Tth = Room thermostat setting

Fan Control: Same as for Conventional Heating System

Pump Control: On: Tr<Tth and Tc>Tr

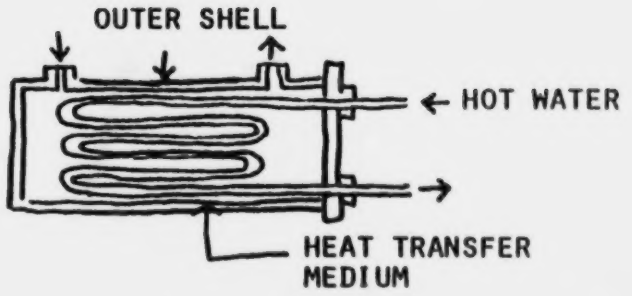
or: Tr<Tth and Ts>Tr

or: Tc>Ts

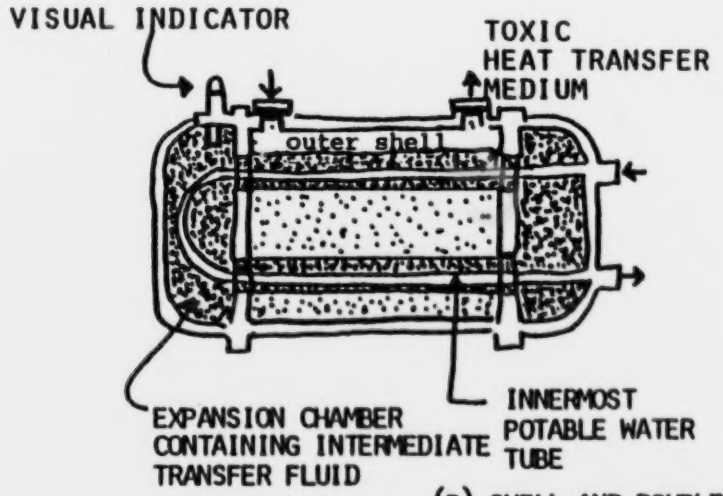
Auxiliary Heater: On: Tr<Tth and Pump is off

TRANSPARENCY # 21

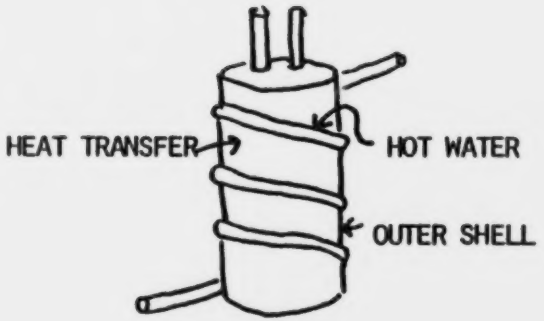
HEAT EXCHANGER DESIGNS



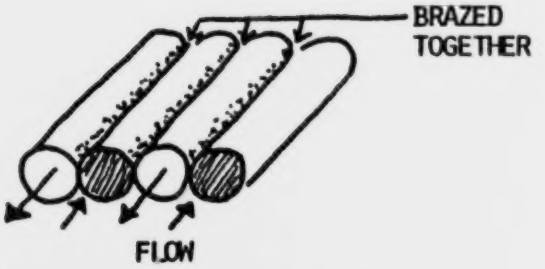
(A) SHELL AND TUBE



(B) SHELL AND DOUBLE TUBE

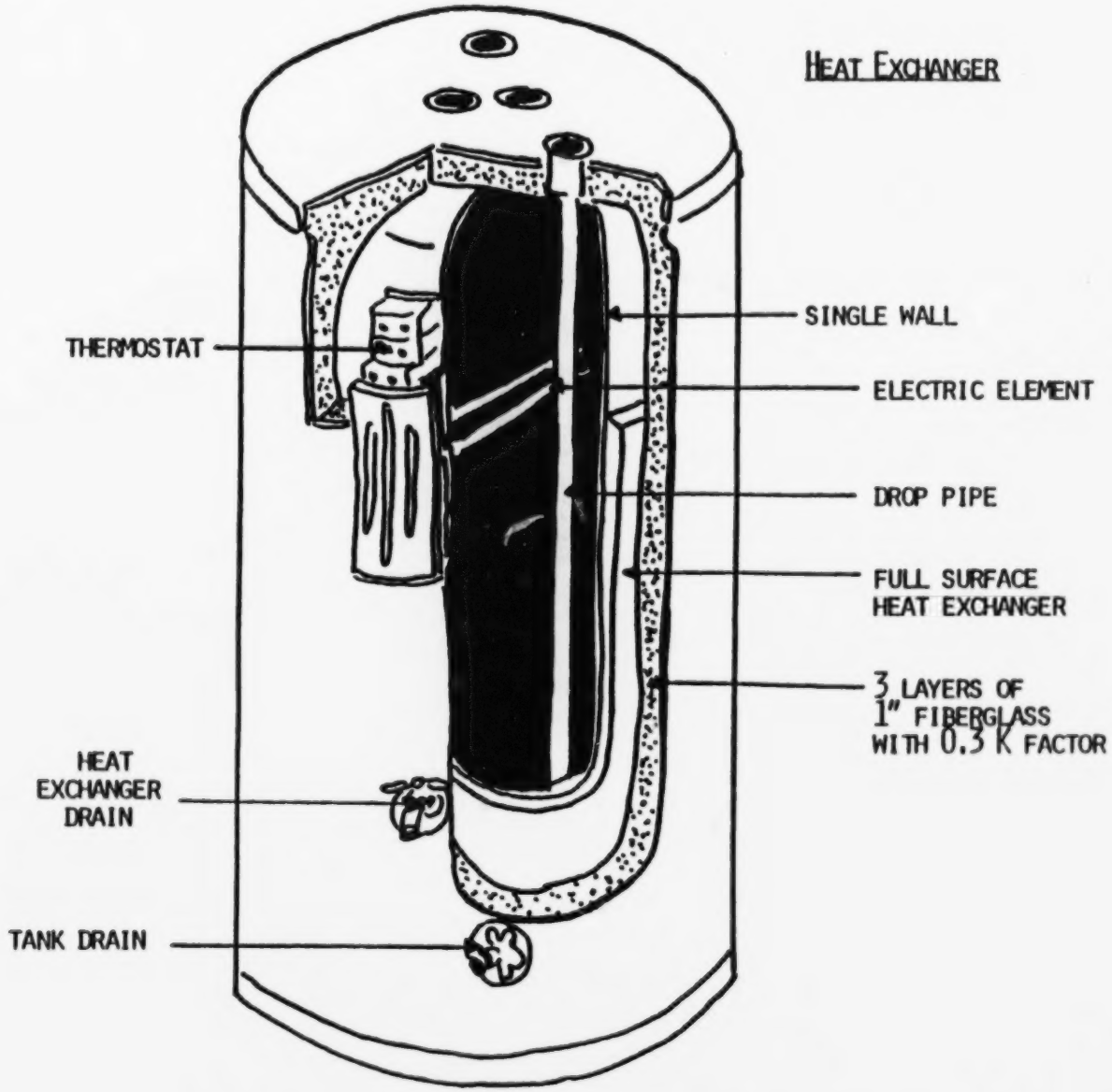


(C) DOUBLE WALL

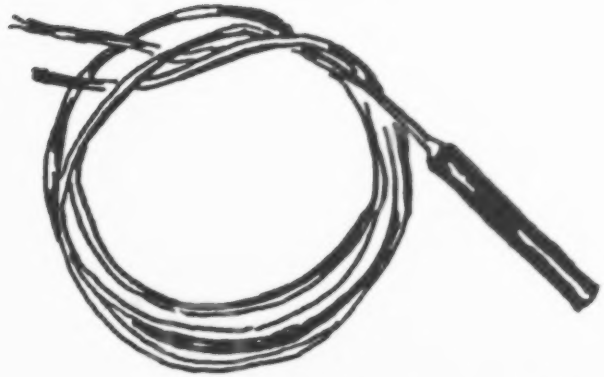


(D) PARALLEL TUBE HEAT EXCHANGER

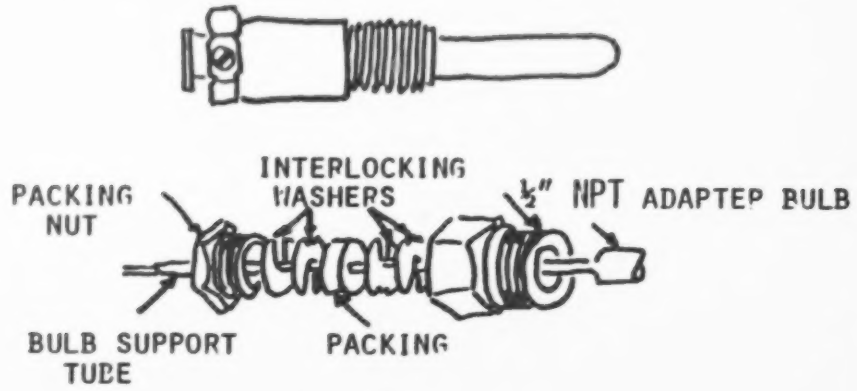
TRANSPARENCY #22



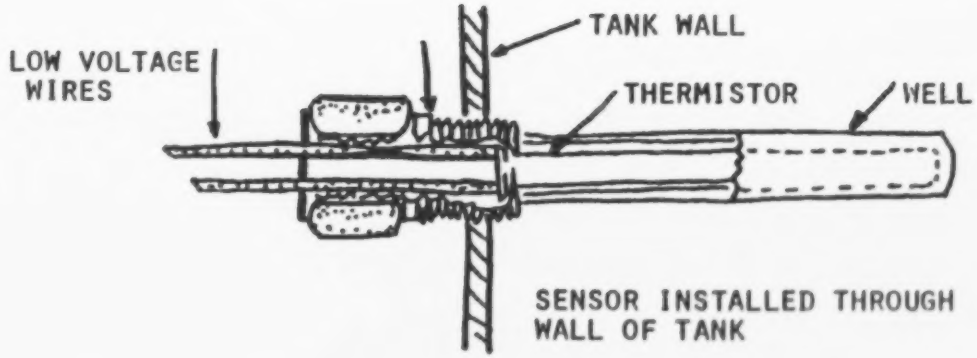
TRANSPARENCY # 23



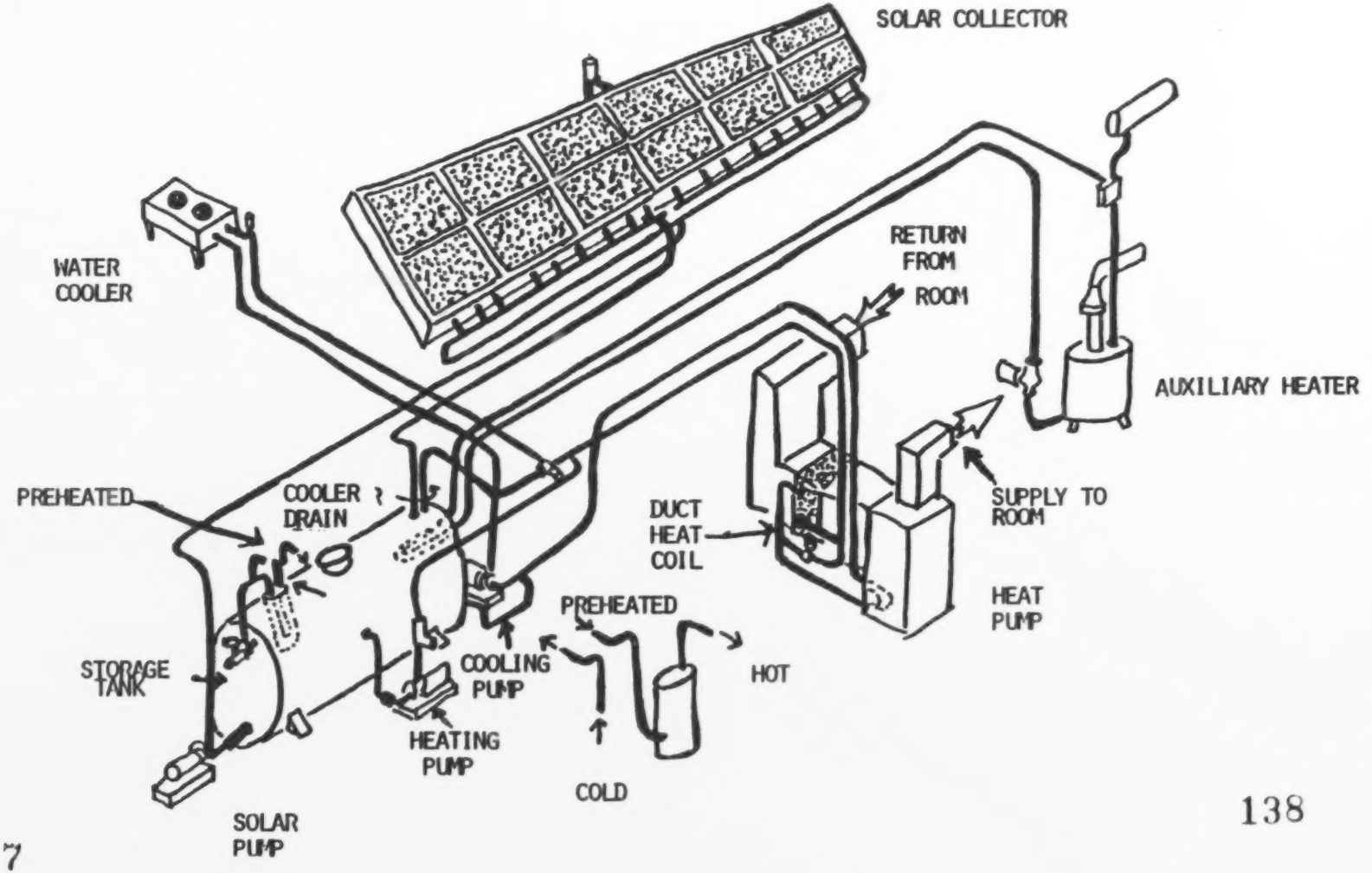
TYPICAL THERMISTOR SENSOR



TYPICAL BULB WELL



TRANSPARENCY # 24



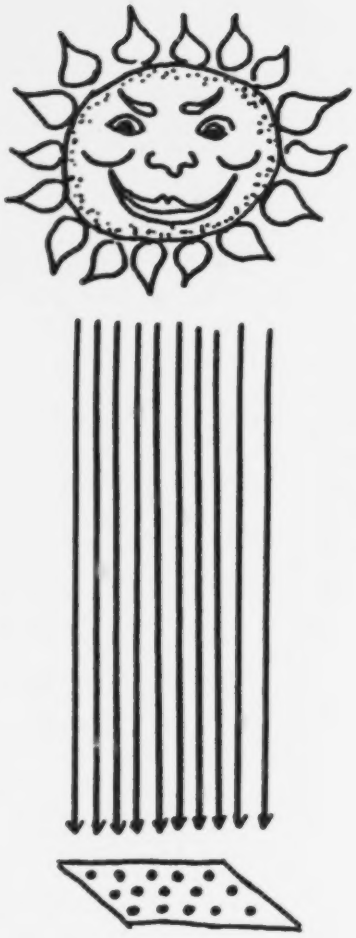
137

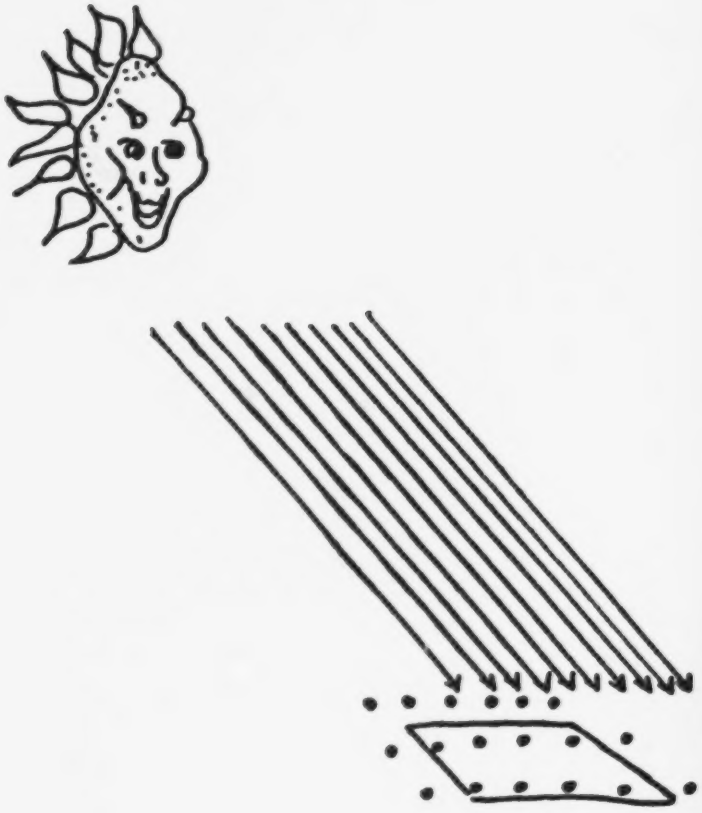
138

WATER TO AIR HEAT PUMP WITH SOLAR ASSIST

TRANSPARENCY # 25

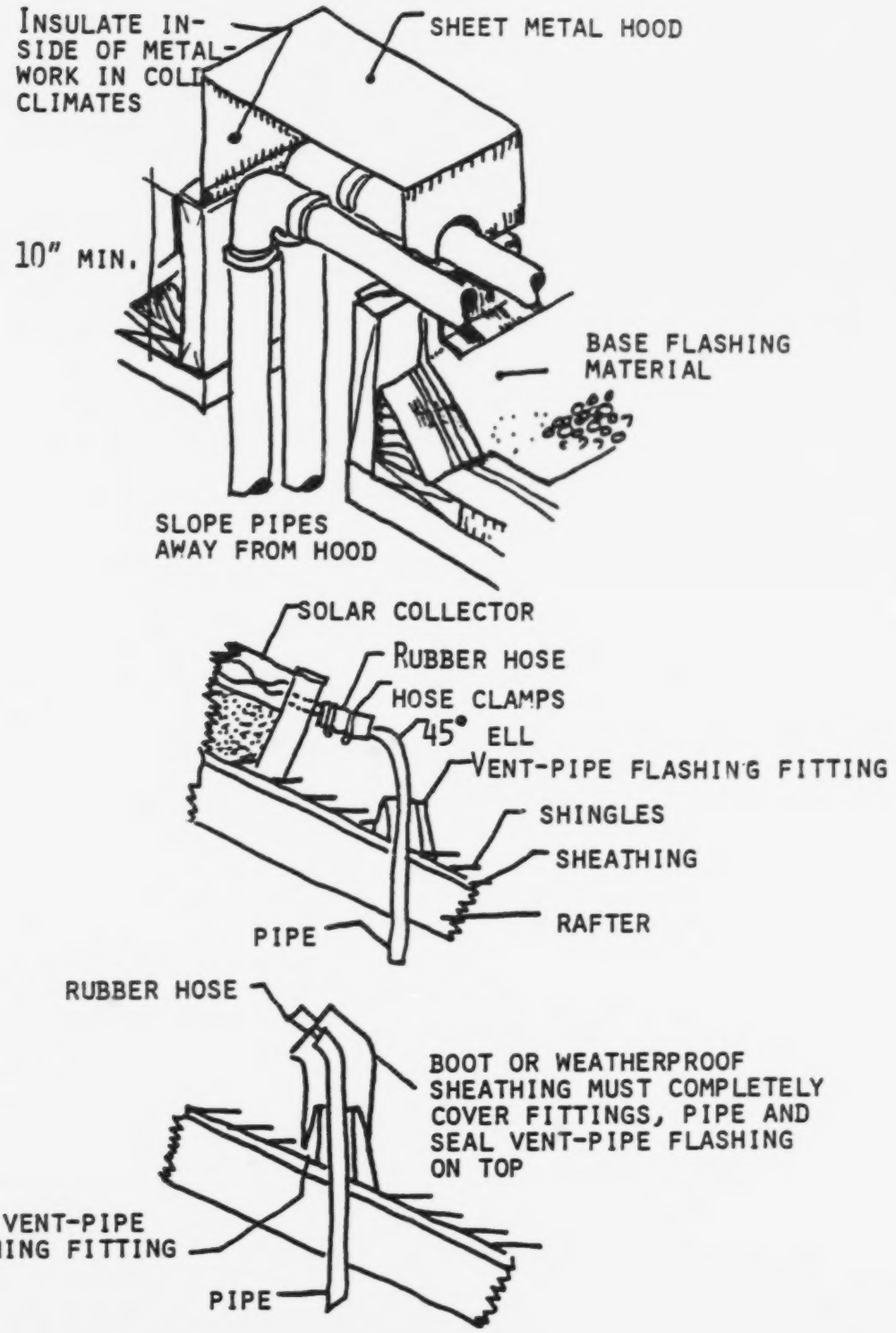
COLLECTOR TILT





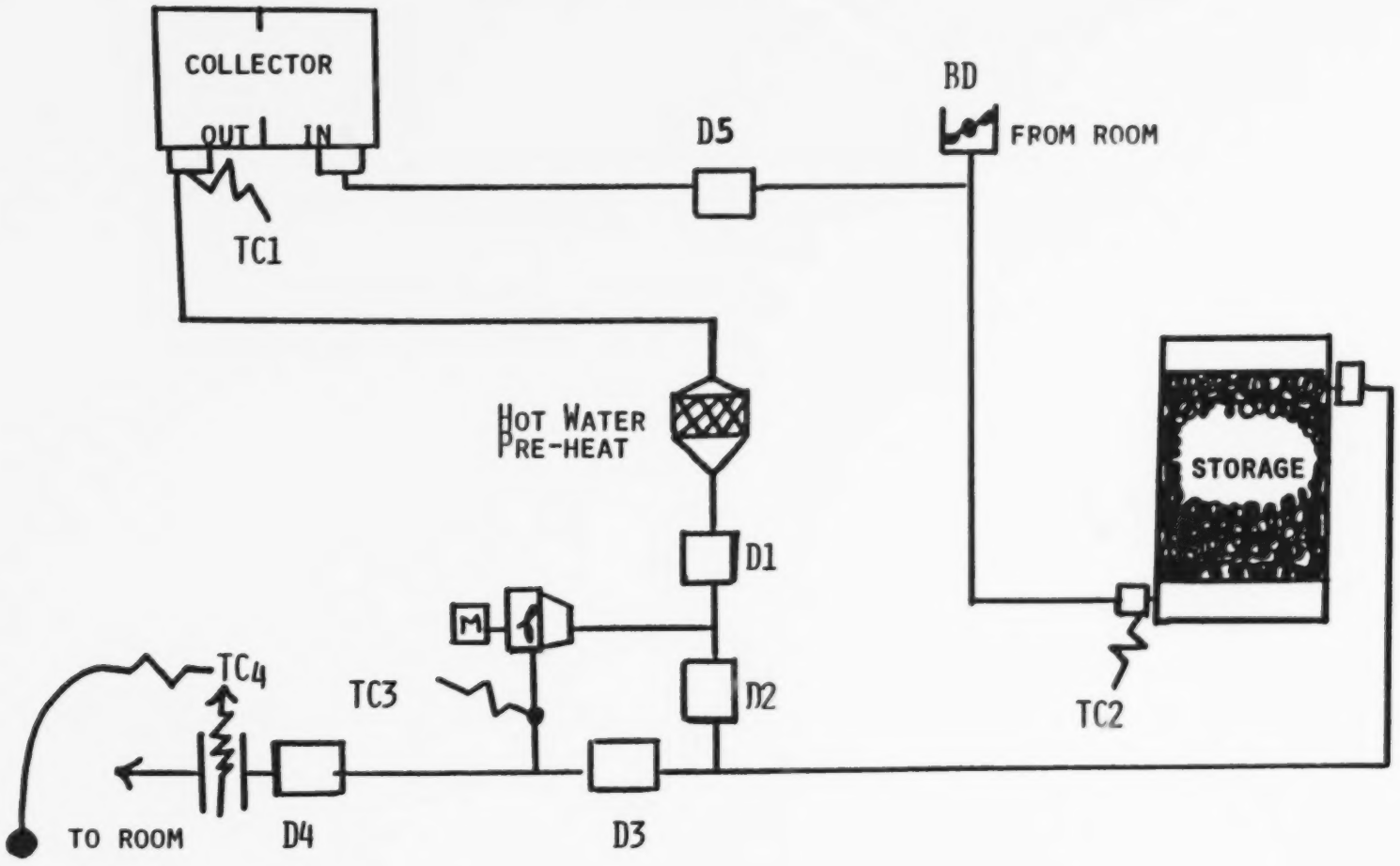
Adapted from The Passive Solar Energy Book, Mazria, 1979.

ROOF PENETRATION



TRANSPARENCY # 27

AIR SOLAR SYSTEM MODEL



SYMBOLS:

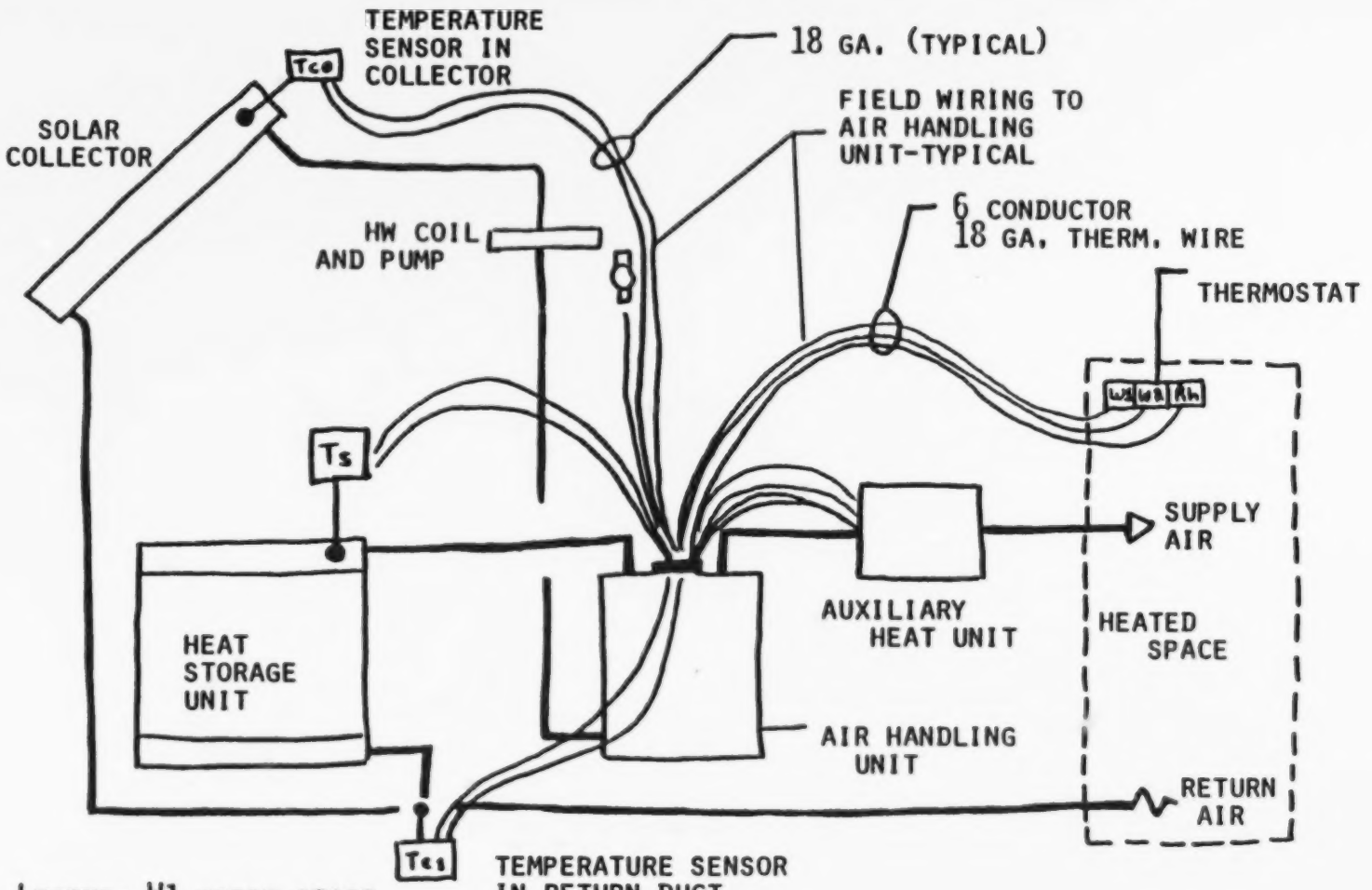
TC = TEMPERATURE CONTROL

D = DAMPER

BD = BACKDRAFT DAMPER

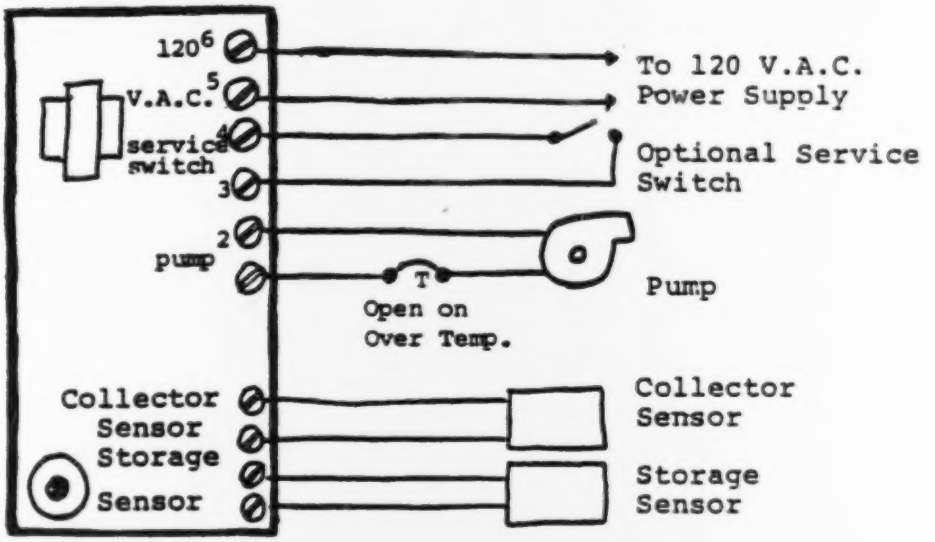
TRANSPARENCY # 28

SENSOR LOCATION



LEGEND: W1 FIRST STAGE HEATING
W2 SECOND STAGE HEATING
RH POWER SUPPLY

TRANSPARENCY # 29



(Penn Controls)

TROUBLE SHOOTING A DIFFERENTIAL CONTROLLER

If circulating device (pump or blower) fails to energize when conditions indicate it should be running, proceed as follows:

1. Use a thermometer and check to be sure the proper differential does exist.

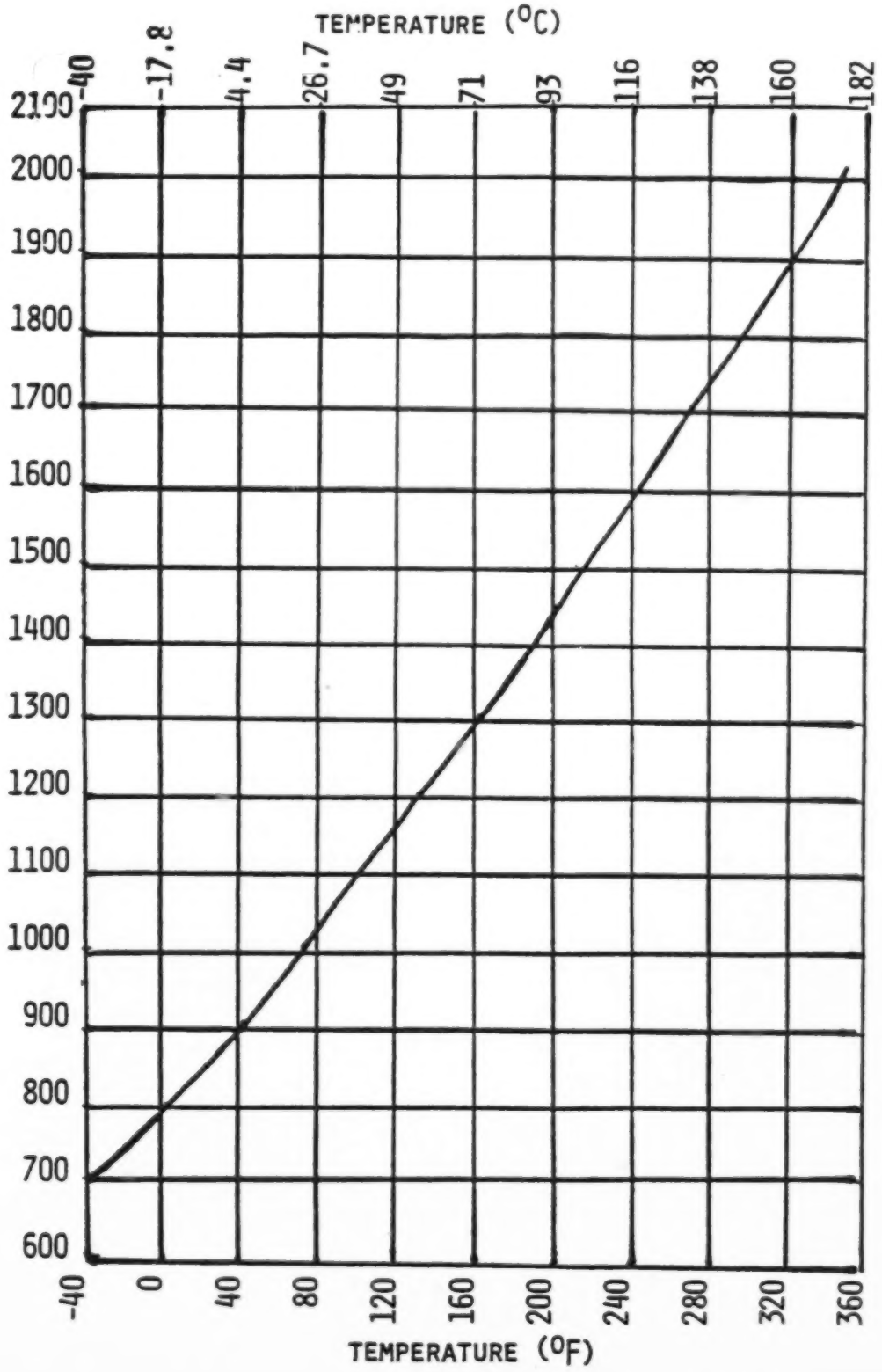
2. Check for proper voltage (120 V.A.C.) supply to terminals 5 and 6.

3. If steps 1 and 2 check all right, disconnect the collector sensor leads from the controller. This simulates a very high collector panel temperature and the pump (blower) should energize. Another way to test this function sould be to reconnect the collector sensor and short circuit the storage sensor. This simulates an extremely low storage temperature, and the pump (blower) should energize. If this step energizes the pump, a defective collector sensor and/or storage sensor is indicated. Refer to sensor checkout instructions.

4. If the sensors are operational per step 3, short circuit terminals 3 and 4 for the manual override, and if the pump energizes, a defective manual override switch is indicated. Check wiring to switch. Replace switch if bad.

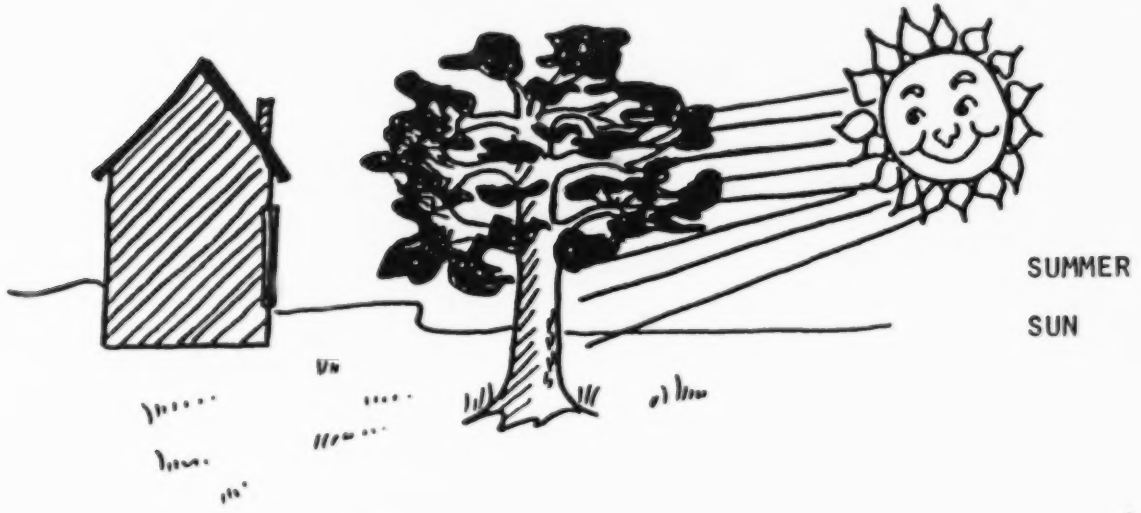
TRANSPARENCY #30

SENSOR CHECKOUT PROCEDURE



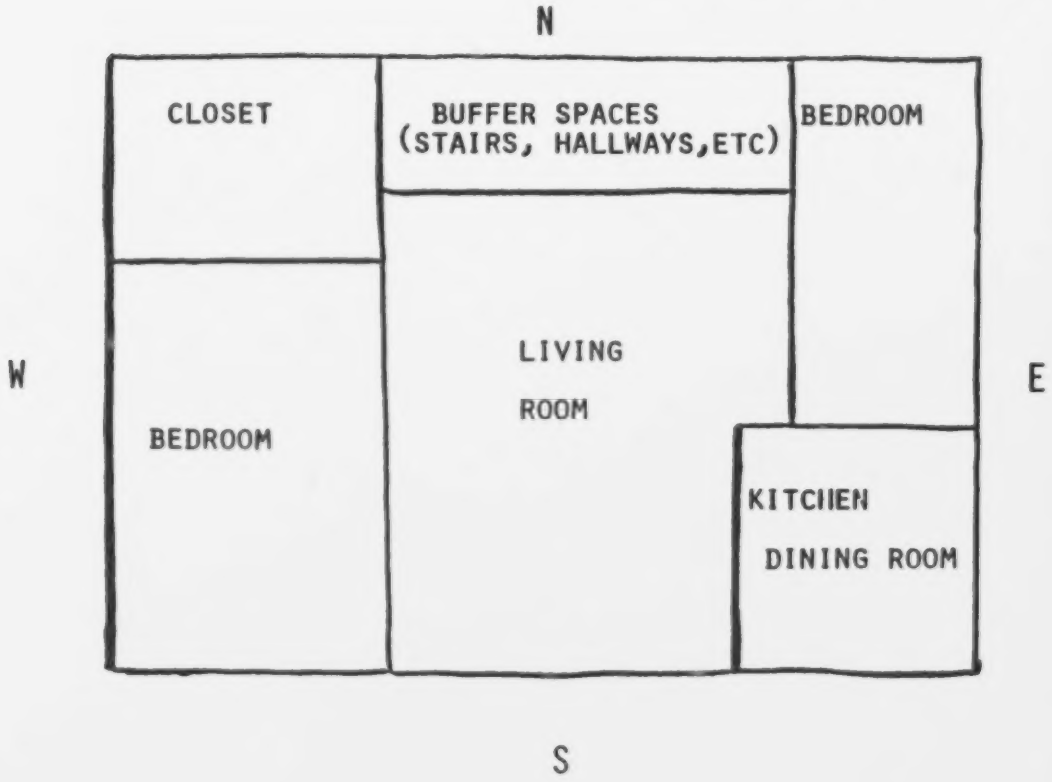
TRANSPARENCY # 31

VEGETATION

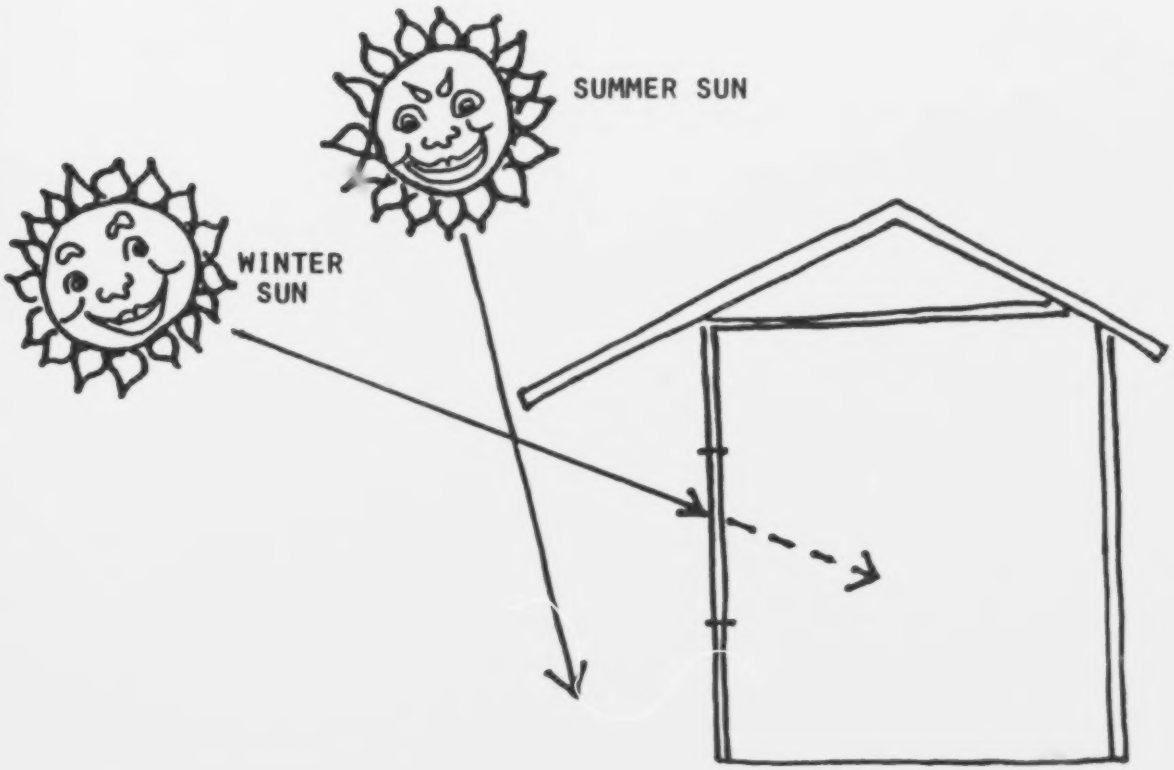


TRANSPARENCY # 32

INTERIOR SPACE LOCATION

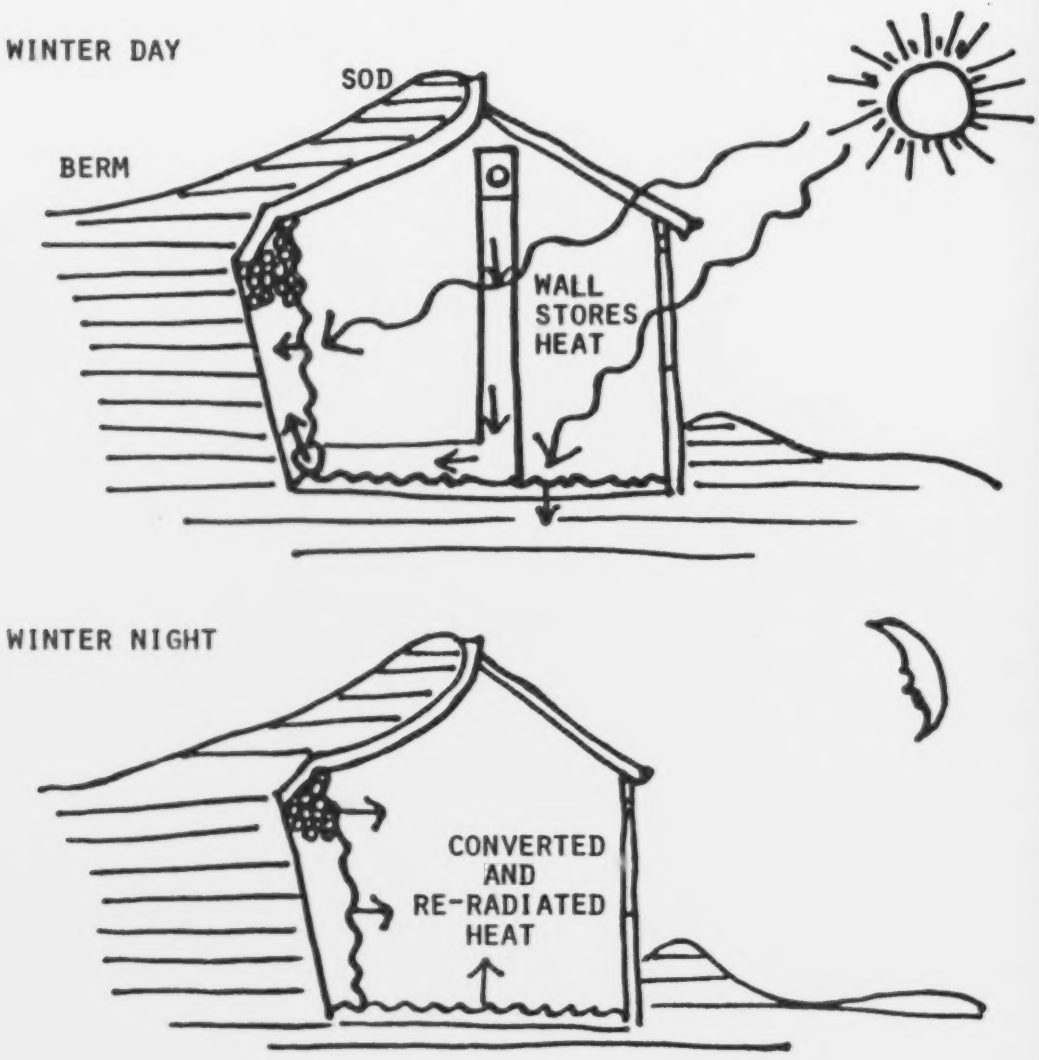


TRANSPARENCY # 33



ROOF OVERHANG

TRANSPARENCY # 34

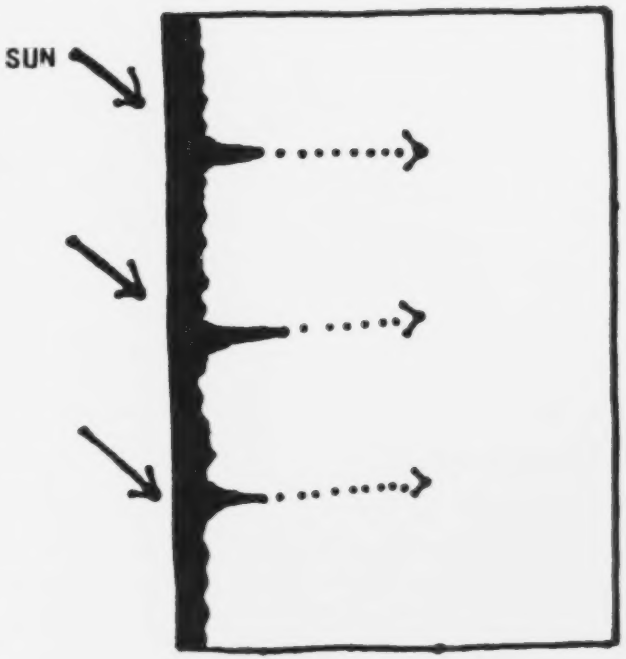


SOLAR HEAT GAIN THROUGH SOUTH VERTICAL DOUBLE GLAZING AT 40 NL. (BTU/SQ. FT.)

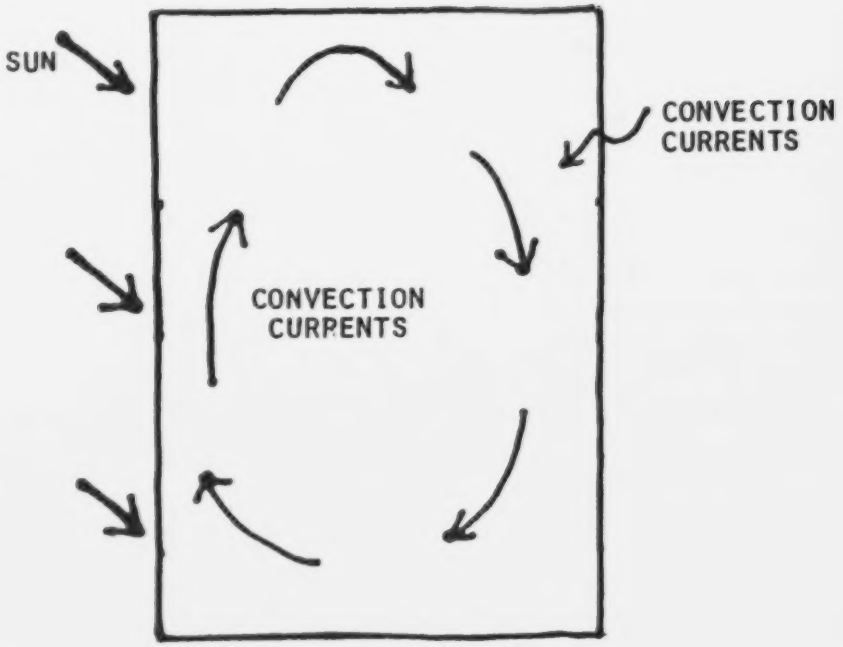
JANUARY 21	1506
FEBRUARY 21	1502
MARCH 21	1244
APRIL 21	838
MAY 21	598
JUNE 21	528
JULY 21	586
AUGUST 21	806
SEPTEMBER 21	1190
OCTOBER 21	1436
NOVEMBER 21	1472
DECEMBER 21	1434

TRANSPARENCY # 36

HEAT TRANSFER IN MASONRY AND WATER



CONCRETE WALL
(OVERHEATS ON SUN SIDE)



WATER (HEATS EVENLY)

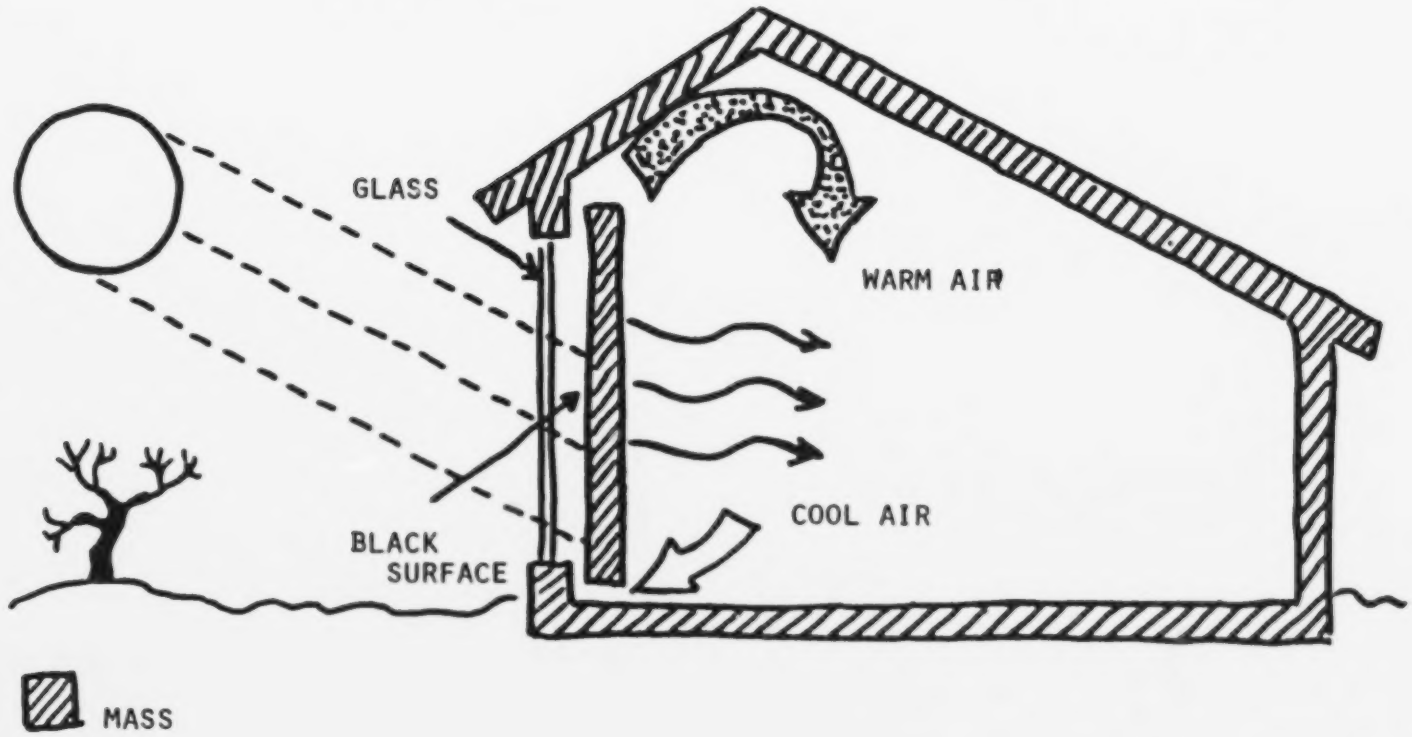
TRANSPARENCY # 37

MATERIAL	SPECIFIC HEAT (BTU/LB/°F)	DENSITY (LB/FT^3)
ADOBE	0.24	106.0
BRICK (COMMON)	0.20	120.0
BRICK (MAGNESIUM ADDED)	0.20	120.0
CONCRETE (DENSE)	0.20	140.0
WATER	0.999	62.32

COMPARISON OF MASONRY MATERIALS FOR THERMAL STORAGE

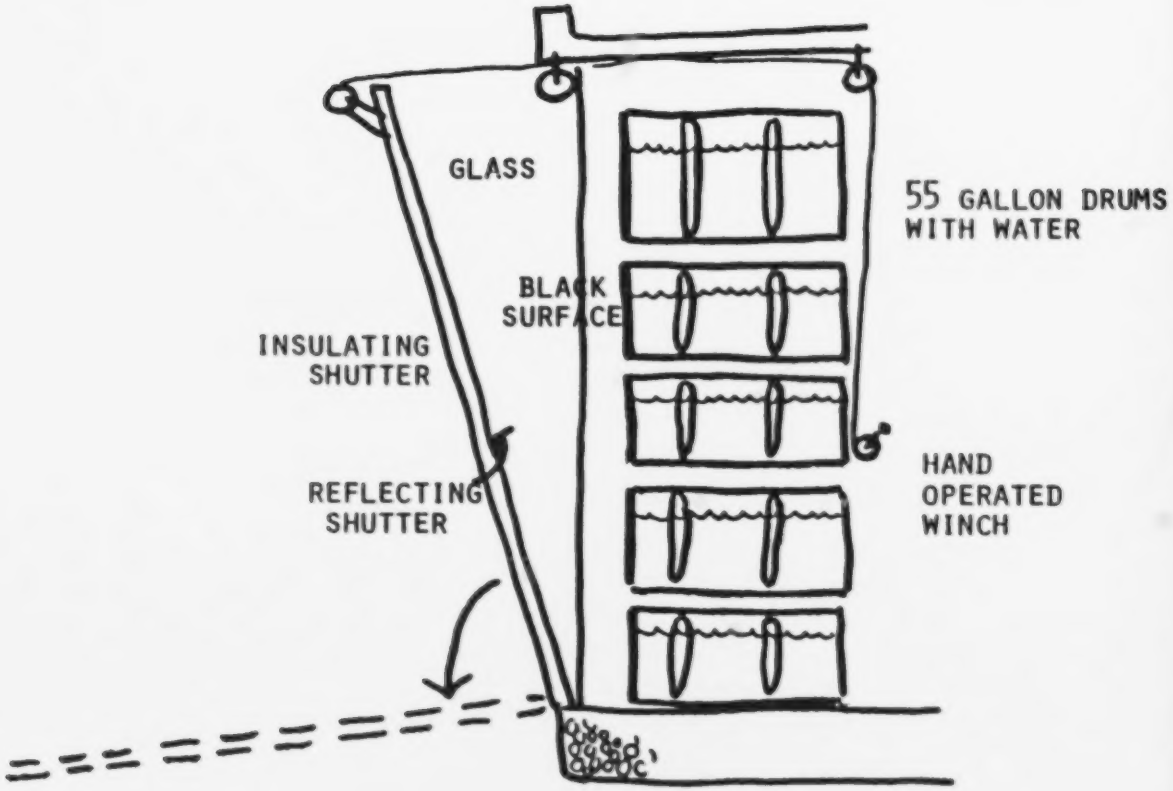
TRANSPARENCY # 38

MASS (TROMBE) WALL



Adapted from Northeast Solar Energy Center, Adult Education Curriculum

TRANSPARENCY # 39

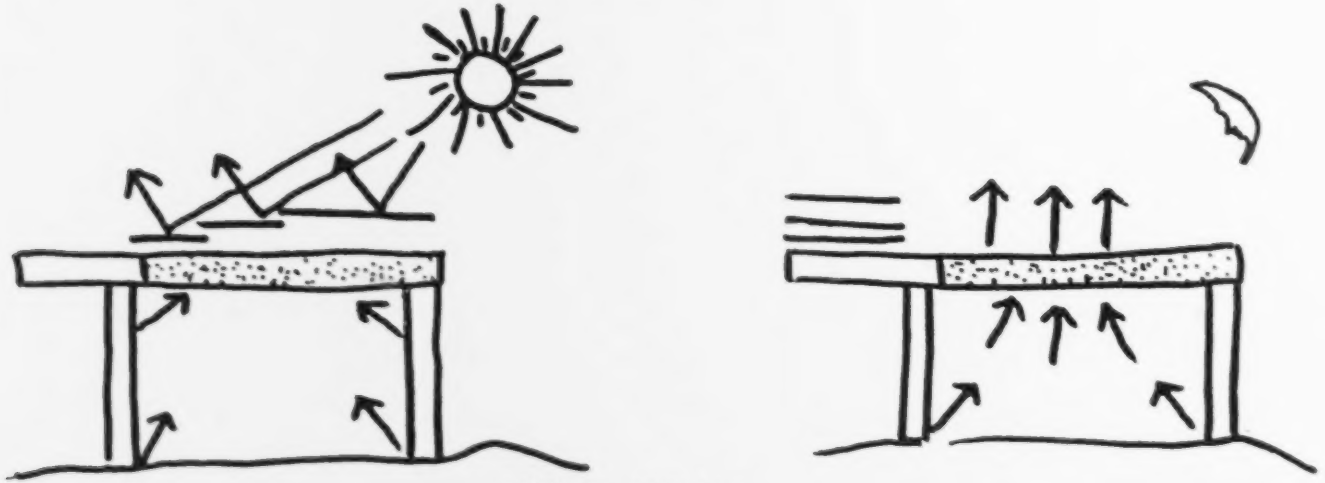


DRUMWALL SYSTEM

Adapted from Solar Energy: Fundamentals in Building Design, Anderson, 1977

TRANSPARENCY # 40

WINTER HEATING



SUMMER COOLING

ROOF POND SYSTEMS OPERATING MODES

Adapted from Solar Energy: Fundamentals in Building Design
Anderson, 1977